DISCOVERY

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The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE DIRECTION OF DAVID S. EVANS

The Future of Medicine

THE need for better organization of the country's health services in general, and of the medical services in particular, has been realized by many people for some years. During the last three years, however, both the need and the possibility of its being met have been emphasized by the problems of health and feeding resulting from the war, and the way in which the Government has assumed responsibility for some of these problems. More recently the publication of the Beveridge Report, with its assumption of a national health service for the prevention and treatment of disease and the rehabilitation of those who have been temporarily incapacitated, has made the need, and the ways in which it could be met, one of the foremost topics of interest and discussion for every man and woman in the country, medical and lay.

In the past the vast majority of qualified medical men have been working as individuals—with much emphasis on their individuality—fighting with the limited technical weapons available to them as individuals, an unorganized guerilla campaign against established diseases. Most laymen have always regarded the doctor as a professional healer, who may be called in to do what he can with the magic of bottle or knife when the trouble has failed to respond to the neighbours' suggestions, or has dragged on untreated for so long that it cannot be further ignored. If the trouble requires to be dealt with by more exalted processes which only a hospital can provide, the very existence and the quality of the services available depend, in most instances, on the private enterprise and charity which go to build up the voluntary hospitals. These conceptions of the function and organization of the health services are out of date. The fact that they still exist is due, in large measure, to the type of training which medical men receive. This training emphasizes, throughout, the relationship of individual medical man to individual patient; and it deals almost exclusively with the purely technical aspects of the diagnosis and treatment of established disease. But the recent appointment of Professor Ryle to the new chair of Social Medicine in the University of Oxford draws attention to the growth of a new school of thought in the profession. Professor Ryle has defined his subject as "medicine activated in its inquiries by social conscience as well as scientific intention, and having as its main purpose the education of scientific and lay thought and the direction of legislation on behalf of national health and efficiency". This is not the place for a detailed discussion of this definition: but it is worth summarizing the achievements of this attitude of mind in the past, and its implications for the future.

The first step was taken just over a century ago when the Poor Law Commissioners published, in 1842, their report of an "Enquiry into the Sanitary Conditions of the Labouring Population of Great Britain". The result has been the development of the Public Health Services, whose activities cover such important aspects of preventive medicine as sewage disposal, the provision of clean water supplies, and the prevention and treatment of the more dramatic infectious diseases. Other practical developments have been the introduction of an Industrial Medical Service —rudimentary though it be—in 1898 and of National Health Insurance in 1911. These are very real advances; but they are not much to boast of as the achievements of a century which has seen the development of medical knowledge to a stage in which it would, if it were properly used, enable most disease to be prevented. It is becoming increasingly obvious that improved organization of the means to health already at our disposal is potentially a vastly more important factor in producing a general improvement in the health of the community than any purely technical advance in clinical medicine. This undoubted fact is a measure of the importance of the implications of Social Medicine. The sense of frustration felt by many medical men working under present conditions is well expressed in the following extract from a letter to the *British Medical Journal*, written by a member of the Public Health Services:

> "It is necessary to point out that the nation cannot get health from medical practice and medical services so long as the nation organizes its social, industrial, and

agricultural activities in a way contrary to the laws of health. All that medical practice and medical services can do under these conditions is to repair the damaged unit so far as possible and return it once more to the stresses and strains which broke it down in the first case. No matter how hard medical practice and medical services work at the pumps the country will founder if it persists in going to sea in a sieve."

This well expresses many of the implications of social medicine, embodying as it does preventive medicine, in the broadest sense, clinical medicine, and rehabilitation. Other implications are: that housing, feeding, and recreational facilities scientifically determined as adequate for the achievement of positive health should be available for all; that routine medical investigation for the detection of disease in its early, curable stages should be available for all; that the standard of medical aid available to the individual should cease to be governed by his ability to pay, or his willingness to accept charity; that sickness in a family should no longer lead to financial loss, with the vicious circle of lowered standards of living leading to further sickness; that the manufacture and sale of drugs should cease to be in the hands of profit-making private concerns who often advertise them in a way deliberately calculated to mislead the public; and finally that the benefits under a national scheme of insurance against disease, whatever its scope, should no longer be administered by private, competing concerns without uniformity.

There is great opposition to the practical realization of these and similar ideas, many of which are embodied in whole or in part in the proposals of the Beveridge Report. Much of it comes from the threatened vested interests, from those people, inside and outside the medical profession, whose money, life's work, and loyalties are staked on the continuance of the present state of affairs; far too much comes from apathy based on ignorance about this present state of affairs and failure to appreciate the potentialities of the future. Success can be achieved if those who are not afraid to think scientifically are sufficiently active in developing a body of informed opinion to overcome this opposition.

Changes are on the way, but they will be the right changes only if we do all in our power to ensure that they are directed not by the representatives of the opposition, but by men and women with disinterested social consciousness and vision.

The Shape of Pebbles

In various industrial processes cast metal components are often given a preliminary smoothing by blasting them with sand or by rubbing their surfaces smooth by turning them in a mill with small shot. The sheets of metal upon which this magazine is photographed before being printed are somewhat similarly treated. This smoothing or abrading process is an imitation of the natural abrading processes by which smooth pebbles are formed, and it forms the subject of a recently published study by Lord Rayleigh.

Natural pebbles are usually not symmetrical, and this lack of symmetry would make any exact discussion extremely difficult, but fortunately there are some pebbles which are symmetrical and even a very few which are almost exactly spherical. The scientist undertaking such a study naturally starts with the simple cases, and only passes to more complicated investigations later, when the principles operating in the simple cases have been thoroughly understood.

It was found that the symmetrical natural pebbles were not elliptical in shape, but bulged out more than a true oval of the same overall dimensions, and thus natural pebbles have a rather flattened shape. Some of the very flattened ones had such well-developed bulges that the top and bottom faces were hollowed out.

In order to study the formation of these symmetrical pebbles, artificial pebbles of chalk were made by shaping the chalk in an elliptical hole in a brass template. To simplify matters all the artificial pebbles were made with one circular section, so that they were really spheres which had been stretched or compressed in one direction. The artificial pebbles were churned in a box with various sorts of abrading material—lead shot, tin-tacks, or steel nuts being used. It was found that the effect of abrasion was to make the artificial pebbles more spherical in shape, but there were one or two exceptions to this. As might have been expected spherical pebbles retained their shape and wore down evenly all round.

There is a discussion of the factors which influence the wearing process. It is clear that any small projections will be worn down, and sharp or rectangular edges rounded off, so that it might be suggested that the important factor was the curvature of the surface. However, it is interesting to note that the wear-and-tear in any particular spot depends not only on the shape of the "pebble" at or near that spot, but on the whole shape of the specimen. We can see how this comes about by thinking of a rectangular "pebble" with flat faces and sharp edges. Since the faces are flat they should wear evenly all over, but in fact they wear hollow. The reason is fairly easy to see, and applies when the size of the pebble is not many times greater than the size of the abrading objects.

The "pebble" is being rolled about in the box and the steel nuts, say, are being hurled at it from all directions and knocking tiny pieces off, so that it gradually wears down. It is easy to see that the corners will be knocked off first, but a nut striking an edge will on the whole be thrown clear, so that the edges will wear down; but just because of this fact, the faces near their edges will have a temporary immunity. On the other hand, the centres of the faces will be exposed to the full shower of nuts, and will wear hollow.

Chalk "pebbles" were used because the wearing was rapid enough to be followed, but presumably much the same results will apply to other kinds of material.

Apparently only a small amount of work has been done on this subject, but it forms an excellent example of how a scientist may often start an investigation from a simple thing like a smooth pebble, and draw conclusions which may be of interest in many other branches of science, in this case in geology and engineering.

Atmospheric Pollen and Hay Fever

The fact that many people experience in the presence of certain plants persistent attacks of sneezing has been known from very early times. Hay fever, the popular name for a

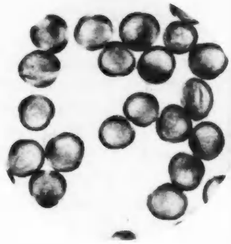


FIG. 1 (*Left*)—POLLEN OF GOAT WILLOW (*Salix Caprea*) enlarged 300 diameters.—The willows are adapted for insect pollination, but their pollen is often air-borne, sometimes in considerable quantities. Goat Willow has been reported as a cause of hay fever. (*Photograph by courtesy of F. J. Pittock, F.R.P.S.*) FIG. 2 (*Centre*)—POLLEN OF QUAKING GRASS (*Briza media*) enlarged 300 diameters.—Grass pollens of different kinds are very uniform in appearance though they vary widely in size. During the greater part of June and July grass pollens enormously outnumber all others in this country. (*Photograph by courtesy of Llandough Hospital, Cardiff.*) FIG. 3 (*Right*)—POLLEN OF MUGWORT (*Artemisia vulgaris*) enlarged 300 diameters.—*Artemisia* pollens characterize the final phase of the pollen season in this country, though their numbers are small compared with those of anemophilous composites recorded in America. (*Photograph by courtesy of Llandough Hospital, Cardiff.*)

catarrh of this kind, was recorded over a hundred years ago, but the true nature of the complaint was not established until 1873. In that year Charles Blackley, a Manchester physician and himself a sufferer, published the results of researches which proved that the onset of hay fever is related to the presence in the air of a certain minimal quantity of flower dust or pollen. Blackley exposed microscope slides smeared with an adhesive mixture and afterwards counted the number of grains which had been caught on each square centimetre of surface. He found that when the numbers reached 20–25 per day he began to experience symptoms and that when they rose to 60 he had a serious attack. He showed that at these times 95% of the pollen which fell on his slides came from the flowers of grasses.

Blackley thus discovered that he and many other people were, to put it in modern terms, allergic to pollen. Allergy may be described as a hypersensitivity or idiosyncrasy toward any substance which may affect the body. Thus a person who is allergic to shellfish may develop nettlerash after eating winkles; while one who is allergic to feathers is likely to have an attack of asthma after sleeping on a feather bed. It is generally supposed that the active substance in each instance is some kind of protein to which the subject is hypersensitive: but in regard to pollen there is not complete unanimity: its effects have also been attributed to polysaccharides and to fats. However, the chemical nature of allergen does not seem, in view of the therapeutic methods at present in use, to be of much immediate importance. Once the causative agent has been diagnosed the method of treatment consists, briefly, in injecting under the skin, minute but gradually increasing amounts of an extract of the kind of pollen concerned. How closely it is necessary to identify the pollen in order that the extract may be effective is still an open question. Successful results have been obtained by treating hay fever due to our native meadow grasses with an extract obtained from sugar cane pollen: which would seem to show that sensitivity to grass pollen is all one. It seems unlikely however that the same would apply for example to all composites.

After Blackley's time no further studies of atmospheric pollen seem to have been undertaken until about 1917, when the method was revived in the U.S.A. In the course of the next two decades a nation-wide survey was carried out, and it became apparent that the grasses, though responsible for much summer catarrh, were of less importance than the ragweeds (species of Ambrosia, a genus of the Compositæ family). Tree pollens also were found to be abundant in spring and to cause a certain number of cases of pollen catarrh. The maintenance of pollen observation stations has now become one of the normal activities of the public health service in America.

Research on atmospheric pollen has been undertaken in recent years in other parts of the world. On the Continent of Europe the only important investigation of this kind was carried out at Davos, where the pollen catch was recorded week by week for two successive years in 1934 and 1935. The first year's continuous record of pollen precipitation ever made in Great Britain was carried out last year at Cardiff. The method adopted was essentially similar to that employed at Blackley: microscope slides coated with glycerin-gelatin containing fuchsin were exposed in a horizontal position, one every twenty-four hours, in such a way as to allow the air to pass over them while they were protected from the weather. The slides were afterwards mounted and examined microscopically, and the pollen grains identified as far as possible and counted. The results have shown that, in this country, there are during the season three fairly well-marked pollen phases dominated by trees, grasses, and herbaceous dicotyledons respectively. These three phases are the counterparts of those observed in America, but it is clear (as was to be expected) that the amount of pollen shed by herbaceous dicotyledons is very small compared with that of the ragweeds and other composites in the U.S.A. At the

FIG. 4.—Plants showing various responses to growth substances. *A* shows three tomato plants of which the centre one has been treated with one part in a million of illuminating gas and the right hand one has been treated with lanoline containing naphthalene-acetic acid. In the pair of tomato plants *B*, the left one is untreated and the right-hand one has been induced to grow roots on the top of the cut stem by application of the same hormone. *C* and *D* are Taxus and Dahlia cuttings showing root-growth induced by another hormone, indole-butyric acid. *(Photo by courtesy of Dr. P. W. Zimmerman)*

same time the possibility that a certain relatively small number of hay fever cases may be related to our native anemophilous composites cannot be ruled out.

While it seems likely that the general conclusions formed from the Cardiff survey will apply elsewhere in Britain, it is probable that the order of importance of the different kinds of pollen will be found to vary from one part of the country to another, and it is almost certain that at different places any one species will reach its maximum at different dates. Quite probably at localities close to the sea—especially on the west—the air will be found to be almost free from pollen when on-shore winds prevail. In order to test these suppositions additional pollen observation stations have been set up, by the courtesy of the authorities of the various institutions concerned, at four centres in England, two in Wales, and two in Scotland. Already it is known that the 1943 pollen season began throughout Great Britain before the end of January.

Plants with Whiskers

PLANTS can be made to grow on their stems curious growths which look like whiskers, but which are, in reality, roots. This amazing effect can be obtained by treating the plant with an ointment containing a chemical substance known as indole-acetic acid. There are many chemically related substances which have a similar effect. Indole-acetic acid is known as a plant hormone.

Hormones are remarkable substances. In ourselves a hormone produced by the pituitary gland (situated under the brain) controls our growth. Over-secretion of it produces giants like the fighter Primo Carnera, and under-secretion produces dwarfs. Other hormones control sex, others control the water content of our tissues, and so on. These substances are poured into the blood by glands called "endocrine" glands. There is no evidence that plants have endocrine glands, but they definitely have hormones.

One chemical substance when mixed with lanoline and rubbed on the stem of a plant causes the cells in that region to grow more rapidly and the plant bends over—away from the side where the chemical was applied. This is a growth hormone effect. Another chemical, if mixed with lanoline and rubbed on to the stem, or on to a leaf—or even on to a petal of a flower—will cause roots to grow in these regions. The pioneer of the lanoline method of applying the hormone to plants is Dr. P. W. Zimmerman of the Boyce Thompson Institute for Plant research in America, who was recently awarded a $1,000 prize by the American Association for the Advancement of Science for his work in this field.

The fact that any part of a plant can be made to grow roots by means of this root-growth hormone suggests that it would be useful in persuading difficult cuttings to "strike" more readily. This is indeed the case. Nurserymen are beginning to use the root-growth hormone which is now on the market and accessible to all.

The technique is to dissolve some of the hormone in water and to place the cuttings in it until roots appear—they should require no more than 15 days at most. In the majority of cases roots have grown some days before this. Once the cutting has developed roots it can be transplanted into an ordinary bed and there is no reason why it should not grow to maturity.

Dr. Zimmerman has investigated the root-stimulating activities of large numbers of chemical substances, including the complex organic acids: indole-acetic acid, naphthalene-acetic acid, and indole-butyric acid.

With these and other substances he has stimulated the growth of roots on all parts of such plants as dahlias, tomatoes, tobacco plants, and Jerusalem artichokes. In his greenhouse he had growing a plant known as a "Cissus" vine, on which the aerial roots grew for a length of several feet without forming branch roots. If, however, he treated them with lanoline ointment containing root-growth hormone, adventitious roots were formed in a very short time, often within the space of 72 hours. If spots of oint-

ment are rubbed into the aerial root too close together the roots which they cause to arise join together and grow out as a sort of wing. This will sometimes occur in cuttings if they are treated with too strong a concentration of the hormone.

The root-growth hormone has been found very useful in producing roots on such cuttings as those of the holly, yew, and lemon, which as a rule can only be persuaded with difficulty to throw out roots. Formerly these trees have been propagated only by means of grafting or growing from seed; the first method is expensive and the second is time-consuming and uncertain.

One of the most exciting but not yet commercially feasible aspects of the application of this hormone is its power to form seedless fruits. If, for example, unpollinated tomato flowers are sprayed with a solution of the hormone, they develop into lovely tomatoes—but the tomatoes are different from those so familiar to us, for they have no seeds. All sorts of other fruits which have too many seeds can be produced in the seedless state by the same method. So far this has only been done in one or two experimental greenhouses used by scientists, and the commercial application of this discovery will depend mainly upon whether a method is found of spraying large numbers of flowers cheaply and rapidly.

Even certain gases, such as illuminating gas and carbon monoxide (found in gas coming from car exhausts) may be capable of causing growth of roots in plants, bending of stems, and so on.

The chemical hormones which produce growth, as distinct from those which produce roots, are known as Auxins—derived from a Greek word meaning "to grow". Auxins are formed at the very tips of the actively growing parts of the plant, such as the growing tip of the stem, the extreme tips of roots (after such roots have been formed), and so on. These regions do not form the Auxins on the spot; they elaborate them from some pro-auxin material which is formed in the cells near the growing tip but which is not in itself capable of causing growth to occur.

Probably the most amazing thing about Auxin is that it is produced by human beings, relatively large quantities of it being recoverable from their urine. It has been found too, that oestrone—the human female sex hormone—has a strongly stimulating effect on plant growth if it is added in high concentration to the soil upon which the plant is growing.

During the past fifty years much has been written about the mysterious forces which regulate the growth and development of plants—this recent work, therefore, indicates that plants, no less than animals, are regulated by the chemical substances known as hormones.

Although we talk about growth hormones (auxins) and root-producing hormones as if they were different substances, some of them (for example naphthalene-acetic acid), can cause not only acceleration of growth, and bending of stems but also proliferations and inductions of adventitious roots.

The amazing progress in this study in the last few years makes one wonder if perhaps the story of Jack and the Beanstalk, which tells of a wonderful plant that grew into the clouds in one night, will one day prove not so far from the bounds of possibility.

GEOFFREY H. BOURNE.

The Structure of the Stars

EVER since the end of the last century astronomers have been faced with the problem of how the stars generate their enormous outputs of energy. It was easily demonstrated by Lord Kelvin that the energy could not be produced in the same way as an ordinary fire produces energy, for this source would not keep the sun in being for more than a few thousand years.

This conclusion made the problem even more mysterious, but light began to be shed on it when it was discovered that there were enormous stores of energy locked up in the atoms of ordinary matter. The situation became clearer still, rather more than ten years ago, when it was found by two entirely distinct lines of investigation that the stars all contained an extremely high proportion of hydrogen in their make-up. Now it is known that a helium atom weighs rather less than four hydrogen atoms, and it was also known from experiments on the transmutation of elements in the laboratory that any transmutation which involved a small loss of mass was accompanied by an enormous output of energy.

Thus ten years ago it had been realized what the fuel for stellar energy must be, namely hydrogen. It was also known what the end product of the energy producing process must be, namely helium. Moreover, physical theory could predict exactly how much energy must be liberated in the transition, for the rate of conversion of mass to energy is a perfectly stable exchange rate which is well known from other kinds of investigation.

The gap in this array of knowledge was the answer to the question: "How do the stars perform this trick of conversion of hydrogen into helium?" Tantalizing scraps of knowledge were available. It was known that the process must require enormously high temperatures such as exist at the centres of stars. Several ways in which the conversion could *not* be carried on were known. In particular it was clear that the most obvious way, namely the coalescing of four hydrogen nuclei to form a single helium nucleus was not possible.

Laboratory researches had provided a great store of information on the subject of the kind of nuclear changes which might take place. This was a new sort of chemistry in which elements were transmuted instead of new compounds being formed as in ordinary chemistry. For a long time the scientists interested in this field tried to work out chains of such changes which would convert the hydrogen into the helium in several stages, but they had little success. In some of them it was necessary to postulate some change which had not been observed in the laboratory; in other cases the chain of reactions worked as rapidly backwards as forwards so that there was not a regular production of energy.

Finally, just before the war Bethe and Gamow worked out a chain of reactions which got over these difficulties. All the changes had been observed in the laboratory: the cycle only went in one direction; and most important of all, the energy was produced at about the right rate, and not all in one glorious burst, or only in a meagre trickle.

Whether this theory will stand the test of time remains to be seen. The only possible test is to find out whether a star working according to this plan behaves like the stars which we observe in the sky. This problem has now

been tackled in a recent paper by Dr. Hoyle and Dr. Lyttleton of Cambridge.

The Gamow theory indicates a certain rate for the production of energy depending on the temperature and pressure at each point inside the star. What Hoyle and Lyttleton have done is to apply this formula to the study of the equilibrium of the gases which form the material of a star.

What this type of calculation really amounts to is the striking of a balance at each point of the star between the weight of all the material above the level under consideration and the pressure of the gas and the radiation coming from the deep interior below. In this way the star is built up layer by layer, each layer as it were "floating" on the one below. Finally, when the star is complete one can give an answer to the question: "How much matter can one float on a given output of energy?"

This means that for a star of given energy output, i.e., brightness, there is only one possible mass for the star. For various reasons this "mass-luminosity" relationship is not quite exact, but that there is such a relation is a well established piece of astrophysical knowledge which has been known for some years and which, it has been shown, must hold even when detailed information as to the output of energy is not available.

The rough sketch we have made of the chain of deduction is not quite exact. The picture of layers of matter floating one on top of the other is only true for the outer regions of the star. Near the centre, where the greater part of the energy is generated, this picture is no longer true. What happens there is that the layers are all stirred together and a situation called "convective equilibrium" obtains.

This work must not be regarded as a final conclusion but rather as a beginning. In such a complicated subject there is always the possibility of the discovery of new features which will modify the conclusions: it is always necessary to make assumptions about the value of certain quantities which physical theory cannot as yet define exactly. However, astronomers when considering a new theory always take such considerations into account. What they are interested in is the possibilities of future development, and there is no doubt that the work of Hoyle and Lyttleton provides ample possibilities of this kind.

Elementary, my dear Watson

SOME time ago a man was found lying dead on the pavement of a New York street. The body lay fourteen feet from the wall, and thirty feet above was a ledge from which the victim had presumably fallen. The question which interested the Life Assurance Company was, "Did he fall, or had he jumped?"

The mystery was solved, not by the medical man or the police detective, but as the result of the investigations of a physicist. Physics, as everybody knows, is a science which deals, among other things, with falling bodies, and human bodies are no exception. Dr. Rufus Oldenburger of the Illinois Institute of Technology approached the problem by successive steps of simple assumptions.

He first worked out what would happen to a man of a certain height who lost his balance on a ledge and simply toppled over. If he fell stiffly his feet would leave the ledge when his body was inclined at an angle of 55° to the vertical. Free fall would then begin, in the course of which the head would turn downwards. Movements of the body in the air can have very little effect on the point at which the body would strike the ground. This mode of fall lands the body at the farthest possible point from the foot of the wall which is compatible with a simple fall, for under these circumstances the centre of gravity attains the greatest possible speed at the moment when free fall commences. Any relaxation of the body before this instant only serves to diminish this speed, and so brings it to the ground nearer to the foot of the wall.

These conclusions were verified by Dr. Oldenburger and his collaborator by means of multi-flash photography of falling objects, and he was also able to show that they were not affected by his simplified assumptions as to the shape of the body.

The next step was to consider the possibility of a voluntary jump at the beginning of the trajectory, and the minimum energy which would be needed to land at a given distance from the wall was determined. A further stage was to calculate the distance which could be reached if the victim jumped from the ledge when he had already lost his balance.

Dr. Oldenburger carried out experiments with track athletes to find out how much force a strong man could exert in a jump after he had already overbalanced. It appeared that this force was comparatively small, and that it certainly would not be enough to generate 100 foot-pounds of kinetic energy.

Finally he considered the possibility that the victim simply walked incautiously over the edge. In this case momentum in a horizontal direction is added to the fall, but it is not very considerable.

From Dr. Oldenburger's analysis it became clear that if the victim had simply fallen from the wall, he could have struck the pavement no more than seven feet from its foot. If he had walked over the edge at four miles an hour the distance would have been nine feet. To reach the actual distance of fourteen feet an energy of at least 150 foot-pounds would have been required, and it was therefore clear that the man (unless he was pushed over—a possibility which it was evidently not thought necessary to envisage) must have jumped off voluntarily before he lost his balance.

NOTE

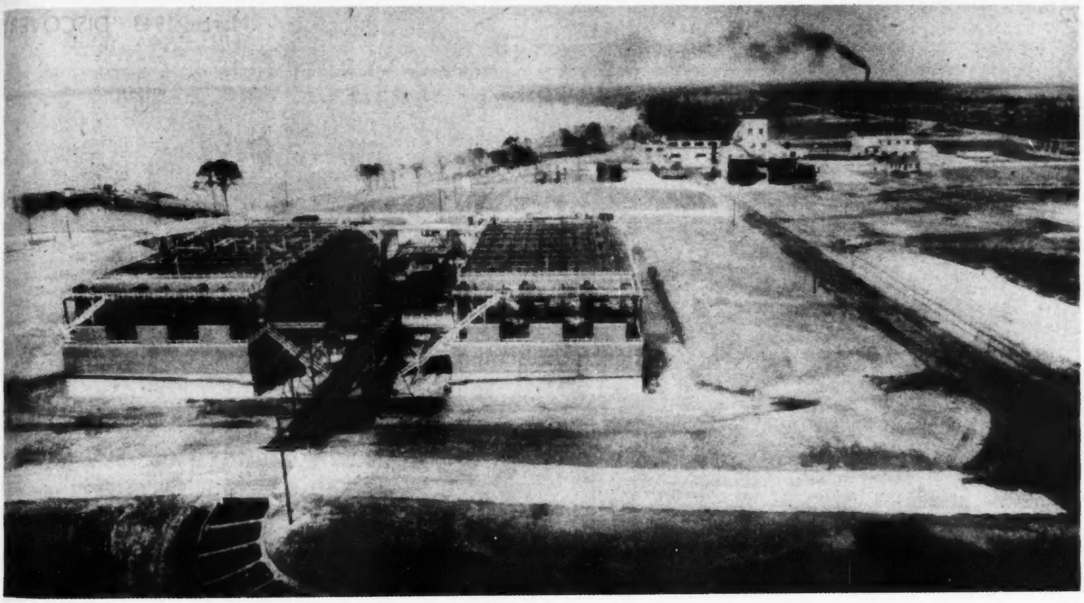
In response to many requests we are including references to the sources of items included in the notebook. For March they are as follows:

The Shape of Pebbles: *Proceedings of the Royal Society*, Vol. 102, p. 177.

Atmospheric Pollen: Private communication.

The Structure of the Stars: *Monthly Notices of the Royal Astronomical Society*, Vol. 102, p. 177.

Elementary, my dear Watson: *Journal of Applied Physics*, July 1942.



Reproduced from " Collateral Readings in Inorganic Chemistry " (D. Appleton-Century Co., New York).

FIG. 1—The Bromine Plant of the Ethyl-Dow Chemical Company of America.

The Sea as a Storehouse

E. F. ARMSTRONG D.Sc., F.R.S.

IN an island country the quest for relaxation normally brings the great majority of us to the coast for holidays, where we make acquaintance with the sea and perhaps also with some of its wonders and the things which live and grow in it. Many people cross the narrow seas to the continent, in others the urge of discovery takes them across the oceans: all are conscious of the immensity of the sea and the fact that it is salt.

Saltness is an indication that substances in some quantity are dissolved in the water, largely common salt, which in many lands is won from the sea by solar evaporation. Sea water contains appreciable quantities of other salts besides sodium chloride, in particular of magnesium and potassium sulphates and chlorides. More complete analysis has disclosed the presence of quite minute quantities of other elements present to the extent of 1 part in 1000 or less, and still others present in even more minute quantity; and a little reflection shows that this must be so, for the oceans are the ultimate receptacle of everything that is washed from the land by the rain and carried by the rivers into the sea. This includes both dissolved and suspended matter.

The wind and the rain and frost—the agencies of destruction and denudation—break down the hills and scour the valleys. Acid waters on the moors, neutral or alkaline waters on the plains, salt water in the sea, all act to bring into solution traces of the most sparingly soluble substances. The quantity of any one of the rarer constituents of the earth's crust in a million parts of sea water is minute and indeed many are only detectable by the most refined methods of the analytical chemist. Some indeed can only be found in the ashes of plants.

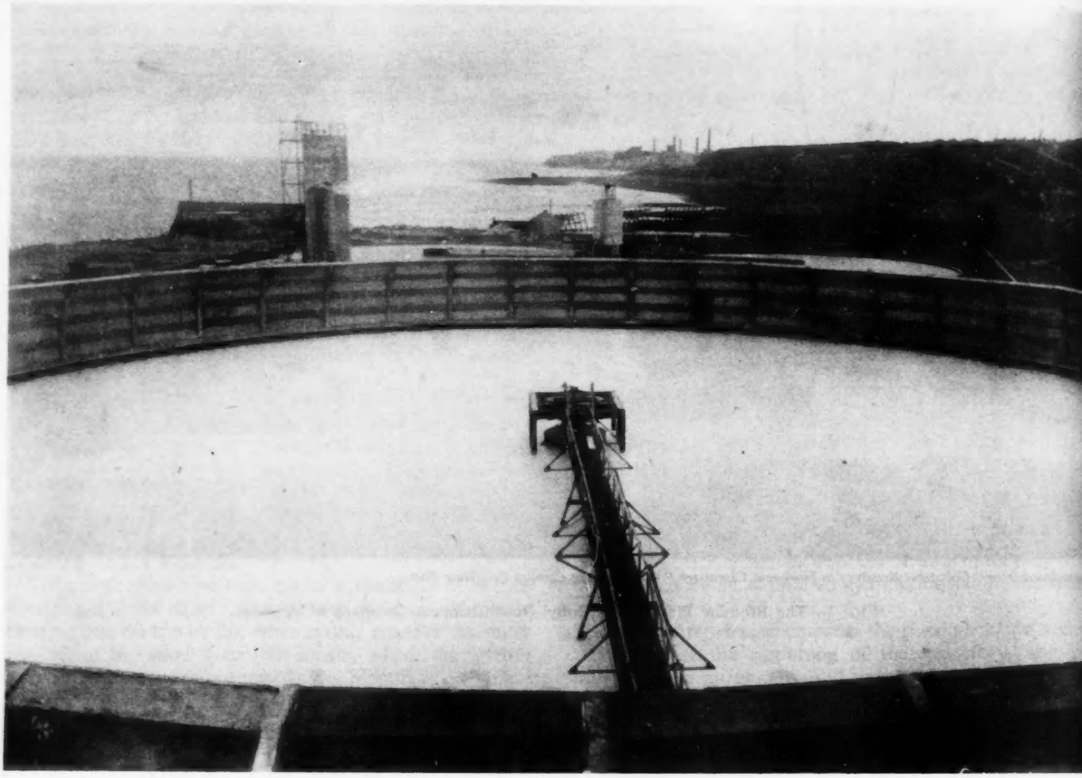
About three-fourths of the earth's surface is water. In bulk this is estimated to amount to 300,000,000 cubic miles.

A cubic mile seems to be a handy unit for statistics regarding the content of minerals. It is, however, a gigantic unit, for in round figures it will contain 6,000,000 tons of magnesia, 4,000,000 tons of potash, 117,000,000 tons of common salt and some 300,000 tons of bromine, which is present to the extent of less than 70 parts per 1,000,000 of sea water.

Such quantities, if extracted, would satisfy the world for a considerable time, whilst a cubic mile of sea is not out of range of a single plant located on an ocean seaboard. The sea clearly forms an inexhaustible store-house of minerals provided that man can find out how to recover them individually at prices comparable with the cost of winning the same substances from the earth.

The Composition of Oceans

Before describing what has been done in this direction, it is well to devote a few words to the composition of the oceans. One theory is that they have been salt from the beginning rather than the alternative theory that they have become so by washing out of salts from the land and



Courtesy of British Periclase Co.

FIG. 2.—Settling Tank, which has a capacity of 2,000,000 gallons of water and approximately 1,000 tons of magnesium hydroxide.

gradual concentration by evaporation of the oceans. This hypothesis is based on the great similarity between the salts of the ocean and the gaseous products of volcanic eruptions rich in chlorides and sulphates of all kinds. The theory explains the main constituents, though it does not necessarily apply to the trace elements where any postulate of constancy of composition is untenable.

Apparently the first quantitative analyses of sea-water were made by Lavoisier in 1872.

It transpires that the variations in the proportions of individual salts to the total salts are very small; sea-water may be regarded as of constant composition, the individual ingredients being considerably dissociated in the dilute solution. This inter-diffusion accounts easily for the uniformity of composition of sea-water throughout the whole ocean, so that the only appreciable difference from point to point is the total salinity of the mixed solutions.

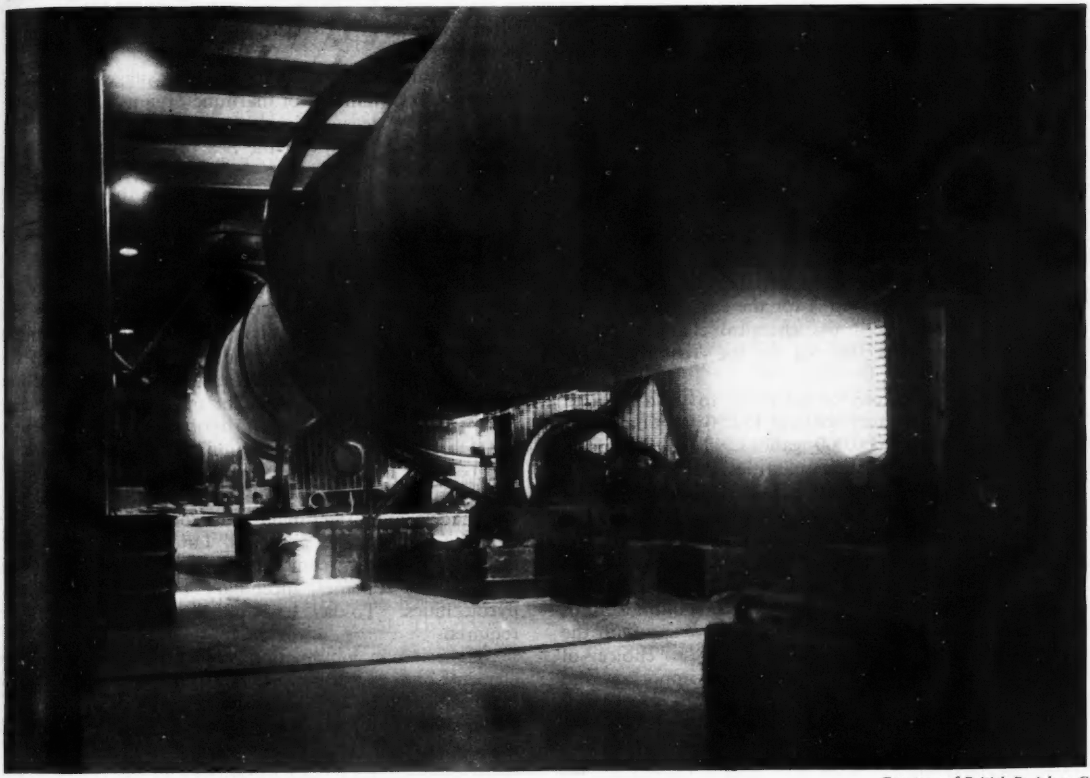
In each of the three oceans the salinity is lower in the equatorial regions where the rainfall is high; there are two maxima—one in the north, the other in the south tropical belts where evaporation predominates; at the poles there are regions of lower salinity. The North Atlantic maximum is the highest at 37·9 parts per 1000 salinity, as a whole the Atlantic has the highest salinity of 35·37. The average of the whole surface of the oceans may be taken as 34·5. There is a general increase of salinity with depth.

Common salt is essential to both man and beast, we need more salt as the proportion of meat we eat diminishes. In Britain and elsewhere there are large deposits of pure salt resulting from the drying up of inland seas in past geological ages: this is recovered by mining or more generally by dissolving the salt underground, pumping up the brine, and evaporating it. The export of salt from England has long been a significant part of our overseas trade: it is the foundation stone of the heavy chemical industry, and salt and the "heavy chemicals" made from it have helped to make Liverpool one of the world's greatest ports.

Less favoured countries where, however, evaporation exceeds precipitation of water are driven to making an impure salt from the sea by allowing it to evaporate in basins in the heat of the sun until it crystallizes: this is termed solar salt.

In England the deposits of salt are not capped with beds of magnesium and potash salts, but at Stassfurt in Germany there is a great thickness of these; and it would seem that in geological times a lake approximating closely in composition to sea-water had dried up completely here leaving everything behind. Stassfurt in consequence enjoyed a virtual monopoly in the production of potash salts and of bromine.

The Dead Sea, and certain lakes in America, represent inland seas evaporated almost to the point of crystallization



Courtesy of British Periclase Co.

FIG. 3.—The Rotary Kilns, which are 160 ft. long, and 10 ft. in diameter, and each burns approximately 300 tons of magnesia per week.

in which, however, the salts have a different composition than in sea-water. Sulphates, for example, are absent from the Dead Sea, a fact which makes the isolation of the other salts more simple. In such lakes it is possible to assume that the salt is derived from rivers or underground springs, which themselves pass through and leach out earlier deposits.

At Seales Lake in California, where evaporation is nearly complete, the salt crust has the appearance of a frozen waste and is so hard that a motor-car may be safely driven over it. At first potash and borax were made from the deposits, a by-product is burkeite, a remarkable double salt of sodium carbonate and sodium sulphate. This lake also serves as a source of more than half the world's very tiny production of Lithium salts. Lithium is an odd element; it is allied to sodium and is beginning to find commercial applications which will no doubt multiply when it is available in quantity at an attractive price. Sea-water contains about 1 part in 10,000,000 lithium.

Bromine

Apart from the quite minor amount of solar salt produced the mineral reserves of the ocean had not been tapped until a start was made with the recovery of bromine in 1924. There is the same element of romance in tapping the resources of the ocean as in turning to practical use the rare gases of the atmosphere: in both the elements sought are present in minute proportions, both are all around us in unlimited quantities.

Bromine in the past was largely a Stassfurt monopoly and expensive, it was used in photography, drugs, and dye-stuffs in quantities measured in pounds rather than tons. The need for it in quantity arose out of the search for substances which could be added to petrol to prevent the engines of automobiles knocking. Midgley solved this problem with a chemical known as tetra ethyl lead dissolved in ethylenebromide—the substance marketed as "Ethyl". At once very large quantities of bromine were needed, and a new cheap source out of the control of the monopoly had to be found.

Work was begun in 1924 by a process which involved the addition of aniline to chlorinated sea-water to form tribromoaniline. After laboratory trials the process was operated on board a boat, the SS. *Ethyl*, fitted out as a chemical factory.

This sailed off the coast of North Carolina and the voyage was successful though it was not repeated: the experience gained was applied to an alternative method which consists in (*a*) oxidizing the bromide in brine with chlorine, (*b*) blowing the free bromine out of solution with air, (*c*) absorbing the bromine with an alkali carbonate solution from which it can be recovered in a commercially desirable form.

Every stage in this process had to be carefully worked out in the laboratory. Sea-water is alkaline, the equivalent of 1 ounce of caustic soda in 1000 tons of water. Even this small quantity gives conditions unsuitable to the oxidation. Acid must be added, the right quantity being 0·27 pound of 96% sulphuric acid per ton of sea-water. These figures are quoted to show the layman how sensitive chemical reactions are to small things, in particular to the acid-alkali reaction of the medium. The biochemist has of late years discovered that the reactions in the living body are even more sensitive to these acid-alkali variations.

The conditions of the operations having been settled by the chemist the next step is for the engineer to design a plant (*a*) to carry out the chemical changes, (*b*) to bring the water from the sea in the required large quantity.

It requires 4000 gallons of sea-water to yield 1 lb. of bromine, so that a factory making 15,000 lb. a day must be able to pump 60,000,000 gallons. The engineering problem of the intake of such quantities, the freeing of the water from extraneous matter and sediment and its delivery continuously to the plant, all at low cost, has been one of the first magnitude: it required great ingenuity and foresight. It is clear that it would not do to put the extracted water back in the sea: it has to be discharged some way off, for example, on the other side of an isthmus where the set of the currents prevents it mixing with the untreated incoming water. Obviously the choice of location of a sea-water plant is both all important and limited.

When the operations are all finished the bromine is obtained in liquid form. Its transport requires special bottles and is costly: it is therefore at once converted on the same site into ethylene bromide.

The first bromine recovery plant, started in 1934, worked efficiently from the outset, producing 15,000 lb. of bromine per day: the yields overall were high. Many thousands of tons are now produced per annum, and bromine to-day belongs to the class of substances of which the cost is reasonable and the supply assured for all time. The chemical engineer and the Dow Chemical Company have had their first victory over the sea.

Calculations indicate that there are nearly 1,000,000,000 tons of bromine in the Dead Sea. As this sea is evaporated to the point of crystallization of the sodium chloride the concentration of bromine is nearly ninety times that in the seven seas, and the ease and cost of its recovery should be less. However, the possibilities of obtaining low costs are superior in industrial America to what they are in Palestine; moreover, any bromine produced here is a long way from the user. It is probable therefore that bromine from the sea will always remain competitive with that produced in Palestine, whilst users will have the advantage of reasonable prices brought about by such rivalry.

Dr. Ernst Bergmann in his paper before the recent British Association Conference on Mineral Resources, reminds us that the Middle East shows a certain affinity to bromine. He recalls that the antique purple, used in the Imperial toga, manufactured in Sidon and Tyre, is a colouring matter containing bromine. Tyrian purple is one of the few known organic bromine compounds found in a living cell. The purple snail from which it was obtained was one of the several known strange instances of which more anon, of selective affinity of cells to a special element.

Dr. Bergmann makes the interesting suggestion that in past ages vast numbers of maritime organisms containing bromine have decayed in the soil in Palestine, and that to-day the hot springs of the Sea of Galilee derive their bromine from this source. It is probable that all the bromine in the Dead Sea is derived from these springs.

Magnesium

This success with bromine partly prepared the way for the next problem, the recovery of magnesium. On January 21st, 1941, the first commercial ingot of any metal taken from sea-water was produced in the plant of the Dow Company at Freeport, Texas, U.S.A. The urge was again economic, the demand for magnesium for aircraft parts suddenly reached vast proportions, for as much as 1,000 lb. may enter into the manufacture of a single plane. Magnesium, the lightest of metals, cost a sovereign a lb. in 1915 and barely a shilling last year: the metal was first made around 1869, mainly as a source of high intensity light for photographic purposes. Later sundry other uses, including fireworks, came along. It awaited war to start its use in aeroplanes, incendiary bombs, and military pyrotechnics. To-day tens of thousands of tons are required.

Magnesium in combination is one of the most abundant elements on the earth's crust. The most favoured source is magnesite, which in particular is used for refractories. Other sources are dolomite, which consists of calcium and magnesium carbonates and carnallite from Stassfurt, which is a double chloride of magnesium and potassium.

If the metal is to be made by electrolysis—hitherto the favoured process—magnesite has to be converted into chloride by briquetting the calcined material with carbon and binding substance and exposing to the action of chlorine in an electric furnace. Since in the course of electrolysis chlorine is evolved the process becomes in theory cyclic, although in practice there is waste through formation of hydrogen chloride.

Faced with the large new requirements, the sea seemed an obvious source of magnesium chloride. The knowledge about the intake of sea-water and the location of a plant was available: in addition cheap power and plentiful supplies of lime, the other necessary raw material, were requisites. The latter also came from the sea in the form of oyster shells dredged from the bottom of Galveston Bay, which, when washed, go straight to the lime kiln. Some 300,000,000 gallons of sea-water per day are drawn into the plant.

Though in practice the recovery of magnesium metal from sea-water involved comparatively simple operations chemically, it is far from being an easy task economically to utilize a raw material which only contains about 1 part of magnesium in 800 of water. Quite unusual chemical engineering methods, equipment, and control, had to be invented. Such work involves research on the grand scale by large teams of chemists and engineers. It is Discovery with a capital D, and costs very large sums of money.

The magnesium is precipitated as hydroxide by means of lime: this is collected on special filters and converted into chloride using for this operation a 10% aqueous

solution of hydrochloric acid which is largely derived from a later stage of the operation. The magnesium chloride is evaporated and dried until anhydrous, when it is electrolysed in suitable cells to produce metallic magnesium. Natural gas is used as the source of power and heat. The effluent water is discharged 7 miles from the intake, which is almost 30 ft. below the surface so as to obtain the highest concentration of salts. The current of sea-water is always in the same direction, which prevents mixing: there is a bromine factory on the same site and the two effluents, the one acid and the other alkaline, mingle.

We have been able to describe the work done in the United States on these materials since it has been widely published in the technical press. Their manufacture has not been neglected in this country and great credit is due to the British Periclase Company and to Dr. H. H. Chesny, and no doubt to others of whom we shall hear more after the war, for their achievements.

There are no oyster shells on the British beach, it was evidently not the one chosen by the Walrus and the Carpenter for their walk. But there was a convenient source of dolomite which is quarried and calcined in shaft kilns and the resulting mixed lime slaked with sufficient water to give a thin slurry.

This slurry is allowed to react with sea-water previously treated and filtered to remove bicarbonate hardness and suspended matter in a special reaction vessel. The calcium hydroxide precipitates the magnesium salts in the sea as magnesium hydroxide whilst the magnesium oxide from the dolomite remains unchanged and in suspension. The resultant mixture is pumped into large circular tanks, where the magnesia settles out and the spent sea-water passes to waste.

The settled magnesia slurry is filtered off by means of rotary vacuum filters, and the paste obtained burned in pulverized-coal-fired rotary kilns. The temperature of firing is varied according to whether it is desired to produce reactive caustic magnesia for the Magnesium Industry, or dead-burnt magnesium oxide for the manufacture of Refractories.

By this ingenious modification magnesium is obtained from dolomite and from the sea by one and the same operation.

Potassium Salts

It would be possible to recover a potassium salt from the sea, but here the economics are not yet favourable. The main use for potash salts is as fertilizers, which command a low price. Moreover, there is a source of potash in the Dead Sea, now under rapid development, which will ensure sufficient supply of these to meet world demand at competitive prices and will destroy the Stassfurt monopoly. There are also similar sources of supply in the United States. The quantity of potassium chloride in the Dead Sea is estimated at 2,000,000,000 tons.

As the concentration of salts is greater at the bottom of the Dead Sea than at the surface, the solution is pumped from depth and evaporated fractionally in shallow natural pans which have an impervious clay bottom. First common salt crystallizes, then a somewhat impure double salt of potassium and magnesium chloride termed carnallite, and finally magnesium chloride: the mother liquors go to the bromine plant. The chemists of the Palestine Potash Co. have made a very thorough study of the sequence of events involved in the evaporation and crystallization, and by an ingenious application of the knowledge of the solid equilibria of the salts concerned coupled with first-class chemical engineering technique are able to produce highly purified potassium chloride.

Over 40 years ago the distinguished Dutch chemist, Van't Hoff, and his pupils, made a profound study of the sequence of events on concentrating sea-water at 25° C. The order in which the various salts are deposited was found to be in very fair agreement with the geological succession as observed at Stassfurt, though there are indications that these dried up at a slightly higher temperature. These celebrated deposits consist of an immense thickness of rock salt, interspersed at fairly regular intervals with narrow bands of anhydrous calcium sulphate capped with beds rich in magnesium and potassium salts. The beds are obviously of marine origin, but a constant flowing-in of water containing salts during the period of evaporation must be assumed to account for the magnitude of the deposit. The inland sea ultimately dried up completely.

The extensive salt beds in Cheshire have no potassium or magnesium salts, and it must be assumed that in this locality the remaining waters went elsewhere before final evaporation.

In the Dead Sea the process of salt accumulation and evaporation go on at the same time. The level is roughly constant, though it varies a little from season to season and decade to decade: evaporation thus keeps pace with the in-flow of fresh water. The Jordan and other rivers bring in 40,000 tons of potassium chloride per annum. The ratio of the various salts remains constant. The relative quantities differ from those in the sea and in salt deposits: in particular there is no sulphate.

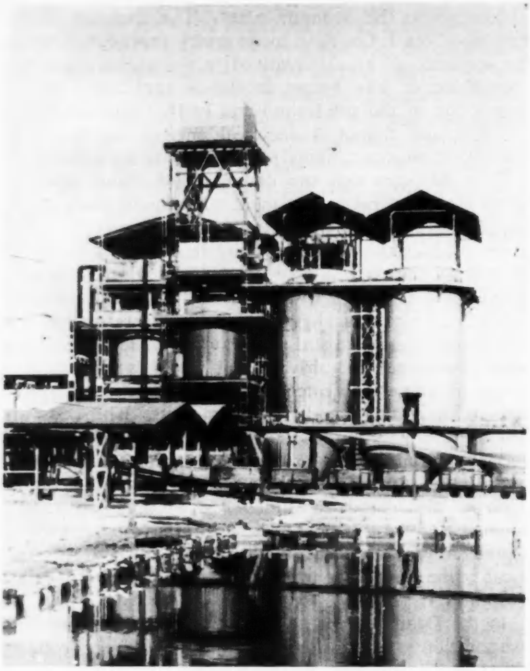
The magnesium content of the Dead Sea is some 8 or 9 times that of the oceans, but here again it is the relative costs at the two sites and the cost of transport to and from them which settles the competitive effort. It is quite clear that given a demand for large quantities of magnesium its manufacture from the ocean will continue.

Dr. Bergmann and the Palestine Potash Co. draw an attractive picture of the potentialities of establishing a large chemical industry there from which the markets in the Middle and Far East can be supplied. The factors are there—and who knows what the future may produce? It must at least be guaranteed as an all-British enterprise.

Phosphates

It may well be that the minerals in the sea can be considered in two classes, namely, (*a*) those present in constant proportion to each other and in relatively large amount, i.e. the salts formed from the elements, sodium, potassium, magnesium, chlorine, bromine, sulphur in the form of sulphates, and (*b*) those present in traces and though universal are possibly in variable amount locally. Fresh supplies of these are being received all the time from the land and returned, as we shall see, to the bottom of the ocean.

Analyses of sea-water showing the amount of the rarer minerals are so far scanty, and it cannot, for example, be said that a particular compound is present everywhere to



Courtesy of Palestine Potash Ltd

FIG. 4.—A Refinery in South Palestine.

the same extent. Evidence is also lacking whether some of them are accumulating or whether they are being deposited either as such or after absorption into the structure of some marine organism. The occurrence of minerals in veins or lodes in sedimentary rocks gives support to the idea of deposition: moreover, the vast deposits of limestone and chalk so characteristic of Southern England are all derived from organisms which have taken up the traces of calcium salts from the sea. Elsewhere calcium has been deposited as sulphate.

At this stage therefore one can state purely as a working hypothesis that whilst the ocean is constant in composition in regard to its main constituents it is variable and even local in regard to the trace elements.

Quite another problem is the fate of those minerals the world over which are constantly reaching the sea either from sewage or by the leaching out of cultivated lands. Whilst these in the aggregate total far less than what is produced by denudation they are of importance because they represent the constituents which are of primary value to man.

One of the most interesting of these is phosphate, of which the mineral deposits are limited in amount and may well become exhausted. Many of the agricultural soils of the world are definitely short of phosphates and their crop-bearing qualities impaired in consequence. A new widely distributed source of phosphate would therefore be of great value and importance.

It has been calculated that the sewage from 5,000,000 people is equivalent to 17,000 tons of rock phosphate in a year, and this happens to be the quantity present in the annual export of meat from New Zealand, which Dominion is the loser of the same amount. The population of Great Britain discards as sewage the equivalent of 150,000 tons of rock phosphate, most of which reaches the sea. An estimate of the annual losses of phosphate from all sources to the sea in the United States amounts to the equivalent of 60,000,000 tons of rock. The world's consumption of phosphate rock is said to be 18,000,000 tons; there are of course other sources of phosphatic fertilizers.

The question may well be asked what is happening to the phosphate, is it being concentrated and removed or deposited? Here is an interesting problem for study. The concentrations of nitrates, phosphates, and silicates in sea-water are subject to considerable fluctuation depending on the activity of the marine organisms, and although the absolute figures may appear insignificant these fluctuations may have a strong effect on the population of the sea. Indeed, this is subject to regular cyclic changes very pronounced in planktonic forms.

The annual crop of plankton depends on the amount of phosphates and nitrates, and there is an apparent relation between the quantity of phosphate available at the beginning of each year and the number of young fish which have had enough food and survived during the ensuing summer months. In temperate seas almost all these salts have been used up during the summer and continued growth depends on new supplies brought up from below by vertical mixing caused by convection currents during the winter, when a rather thorough renewal takes place.

Softening Sea-water

The chemist is already searching for materials capable of selectively absorbing and retaining substances present in small quantities in large volumes of water. Such base exchanging materials are widely used in the softening of hard waters, a process which involves the replacement of soap-destroying and scale-forming calcium and magnesium by relatively innocuous sodium. Natural zeolites were first used for this purpose and later supplemented by artificial zeolites and by sulphonated carbonaceous materials. These last offer the additional advantage of replacing the calcium or magnesium with hydrogen instead of sodium if desired. In this way the dissolved salts can be removed altogether instead of merely replaced, such a process is particularly valuable in water for boilers. They are made by treating coal or lignite with strong reagents such as fuming sulphuric acid, sulphur trioxide, chromic acid, etc.: the active group in these zeolites is believed to be a sulphonic acid group.

Much the same principle explains the action of polyhydric phenol formaldehyde resins. These contain hydrogen (in an hydroxyl group) which readily goes into solution to replace calcium or sodium ions and forms acids. Such resins are reported as physically more stable and faster in action than the other softeners mentioned. There is another group of resins described as amine-formaldehyde, which achieves actual removal of the acids just mentioned. The mechanism is obscure, but it may include both surface absorption and reaction of the acids with the amine group. Resin treatment may convert an ordinary hard water into something approaching distilled water.

FIG. 5.—Evaporation pans in the Palestine Potash Plant

Courtesy of Palestine Potash Ltd.

Naturally experiments have been made along these lines with sea-water with the hope of being able to convert it into drinking water for shipwrecked mariners in apparatus small enough to be carried in lifeboats. The amount of salt in the sea makes this problem a very difficult one and the solution is not yet in sight.

It seems clear that in these base exchangers the chemist has useful tools to effect the concentration of small quantities of dissolved substances. Some technical applications are already known, but we would illustrate what it is hoped to achieve by citing some results obtained with copper by Professor Furnas and R. H. Beaton working at Yale.

Copper

The ideal conditions using carbonaceous zeolites have been determined. The absorption for copper is a function of the ratio of copper ions to hydrogen ion concentrations, or in more simple language there are ideal conditions of acidity favouring the transfer of copper from solution to zeolite. The collection of copper is complete and takes place at a rapid rate of flow of the very dilute solution over the columns of the exchanger. The recovery of the copper when the zeolite is saturated is effected by fairly strong solutions of sulphuric acid: at the same time the zeolite is regenerated for another cycle. There remains as final product a strong solution of copper sulphate.

Putting the results in plain figures rather than in the form favoured by the chemist, it appears that a solution which contained 1 lb. of copper in 6,300 lb. of water is turned into one of copper sulphate containing 1 lb. of copper in 6·87 lb. of water. To do this 1·54 lb. of sulphuric acid (100% strength) are necessary, and simple arithmetic indicates that 1 lb. of acid performs the same duty as the evaporation of 4,200 lb. of water. This illustrates the tremendous difference in energy requirements between the base exchange process and evaporation for the concentration of very dilute solutions and is evidence of the unique possibilities of the use of zeolites.

The Yale achievement of increasing the concentration of copper in dilute solutions is rivalled by that of the oyster which we must be prepared to treat with greater respect after learning that it gargles a barrel of water per day. Around the British Isles and in certain sections of the Atlantic coast oysters become green due to the formation of a pigment containing copper. The amount of copper which an oyster can accumulate is variable, it varies in the Cape Cod variety from 0·16 to 0·24 mg. per oyster and from 1·24 to 5·12 mg. per oyster in Long Island Sound, where the average is 2·5 mg. This last figure has enabled some one to calculate that in Long Island Sound the oysters accumulate about 7·5 tons of copper every year from the sea.

The average content of copper in the sea appears to be of the order of 0·01 parts per 1,000,000. There is more copper in the fresh water coming into Long Island Sound than in the sea, indeed, the amount there fluctuates between 1 part per 1,000,000 at high water and 0·5 parts per 1,000,000 at low tide.

Copper salts apparently have a peculiar effect on oyster larvae inducing their attachment to the substratum and initiating their metamorphosis. The result is that the best settling areas are found on bottoms affected by fresh water, whilst natural oyster beds occur mainly in the mouths of rivers. It has been estimated in the United States that

200 tons of copper are lost in sewage each year per 1,000,000 people, together with 50 tons each of such metals as magnesium, lead, aluminium and titanium. The 10,000,000 people of New York City provide on this recovery ample copper for their oysters.

Copper is well-known as the metal in the respiratory pigment, haemocyanin, which is present in lobsters, shrimps, crawfish, and other shell-fish and plays the same part as iron does in haemoglobin, the respiratory pigment of human red blood corpuscles. It is found in sardines, herrings, salmon, and other sea animals, and is obviously quite an essential element in marine life notwithstanding its lowly proportion in the sea.

A considerable proportion of the trace elements seem to be concerned in the life-history of marine organisms. Where there is plenty of an element the organisms flourish, where it is scanty they are absent. When the organisms flourish they live their allotted span and die, their skeletons falling to the depths of the ocean and decomposing into their constituents. Where there are vertical currents the trace elements are brought to the surface once more and there is renewed growth of organism; when there is no upward current a deposit is formed rich in the trace element. New reactions resulting in the formation of sedimentary rocks take place: we pass from the science of biology to geology. Some of these elements enter direct into the structure of the organism, others—in particular the heavy metals—are believed to be largely taken out of solution by absorption on the surface of the protoplasm, a purely physical phenomenon. This applies to gold and silver.

Gold

A matter in which the more credulous portion of the public is interested is the possibility of obtaining gold from the sea. Gold is present to the extent of 1 part in 1,000,000,000 (1 mg. per cubic meter), which means that 1 cubic mile contains about £20,000,000 worth. Gold has actually been extracted from the sea during a month's working at one of the American bromine plants, but the cost of doing so was several times more than the value of the gold, and it would appear that it will still be cheaper to mine gold in South Africa and elsewhere even when the present mines are exhausted and the reefs have to be followed deeper into the earth at an increased cost of production.

Gold is probably one of the elements which does not stay in the sea, but is being removed by absorption on to the surface of organisms and taken down to the bottom. In agreement with this the bottom sludges obtained by dredging in certain localities contain very much larger quantities of gold than there is in the sea. Indeed, the amount is most variable: estimates in the literature vary from 23 to 1,200 tons of gold in 1 cubic mile of sea.

One may perhaps answer this interesting question by saying that gold will continue to be mined rather than won from the sea for some time to come, particularly since it has few uses other than as a financial token.

Iodine

An element of universal distribution in air, sea and land, is iodine which is of fundamental importance alike to man, animals and plants. It is a constituent of the thyroid gland and if we lack it in sufficient quantity we are afflicted by goitre. Many marine plants have the power of concentrating it, thus the dry matter of deep water seaweed, such as Laminaria, contains as much as 0·5 per cent. Iodine was in fact first discovered by Courtois in 1811 in the ash of sea kelp. Kelp, or *Varech* as it is called in France, has been used for many years for the commercial extraction of iodine even though this practice cannot compete economically with the production of iodate from the caliche in Chile. Certain coral species are said to contain up to 8 per cent of iodine and it is of interest that it is present both here and in the bath sponge in the organic state as di-iodo-tyrosine.

The question of the form of iodine in the sea is still indefinite: it may well be organic. The sea contains 0·001 per cent and is much richer in this rarest of the halogens than the land. It is obviously in a continual state of change, being oxidized and reduced and passing into marine plants and animals. When the seaweed moves lazily to and fro at our feet large quantities of iodine are being withdrawn from circulation. Some of it is constantly being lost through vapourization into the atmosphere, and this is why people living sufficiently near the coast, as the great majority of the population of this island do, do not suffer from goitre in the same way as the population of the great central plains of the United States.

Arsenic and Calcium

The arsenic in the sea exists apparently in organic form and like iodine is concentrated in animals and plants. The lobster has 40-50 parts per 1,000,000, and *Laminaria* twice as much.

There are many points of interest connected with the calcium in the sea: in fresh water it is the most abundant of the three cations—calcium, magnesium, and sodium; in sea-water it is the least abundant as all the time animals and plants are removing it, a fact to which the white cliffs of Dover bears abundant testimony. It is related to the carbon dioxide content of the oceans which is some 15 to 30 times the amount present in the atmosphere, and it is may well be that the carbon dioxide content of the air is regulated by the oceans acting as a reservoir. There is a continual exchange between the air and the surface of the sea which, among other things, controls the acidity of the sea-water to which much of the life of the ocean is acutely sensitive. Further in the sea, as on land, plants use carbon dioxide as the basic source of carbon for the building up of organic compounds.

When the carbon dioxide in solution in sea-water is reduced the conditions are favourable for the deposition of calcium carbonate. The building of shells by animals which live on the sea bottom and of the smallest Protozoa is an interesting subject. It accounts for an annual deposition of 1,400,000,000 tons of calcium. Shells are of two classes, those containing calcium carbonate alone or with magnesium carbonate, those containing calcium phosphate. As yet we have no clue to the reactions involved in building shells: one minor point is that in tropical waters the percentage of magnesium carbonate is higher.

The relative abundance of the alkaline earths in the sea

(*Continued on page* 87)

The Scientific Control of Milk

J. G. DAVIS, D.Sc., Ph.D.

of the National Institute for Research in Dairying

It is universally recognized that milk occupies a key position in the nutrition of a nation. In this country we have about 3,000,000 dairy cattle, producing annually about 1,100,000,000 gallons of milk. Milk production is increasing, and there is little doubt that the dairy industry is one of our most important industries and that this position will continue to be recognized after the war.

The value of milk as a food is clearly illustrated in Table I, in which it is seen that milk, although a liquid, is in fact richer in many constituents such as protein, fat and carbohydrate than some solid foods. Table II shows the proportion of the daily requirement of various food constituents required by the average adult which is provided by 1 quart of milk. Milk is specially valuable as a source of calcium, vitamin B, phosphorus, and first-class protein.

TABLE I

PERCENTAGE COMPOSITION OF FOODSTUFFS

Foodstuff	*Protein*	*Fat*	*Carbo-hydrate*	*Water content*	*Calories per 100g*
Cabbage .	1·6	0·3	4·5	94	27
Tomato .	0·9	0·4	3·3	94	20
String Bean .	2·3	0·3	5·5	90	34
Beet (cooked).	2·3	0·1	7·4	89	40
Carrot . .	1·1	0·4	8·2	89	41
Milk . .	3·3	3·7	4·8	87·5	67
Apple . .	0·4	0·5	13·0	85	58
Potato . .	2·2	0·1	18·0	78	82
Egg . .	13·4	10·5	0	74	148

The outstanding characteristic of milk is its perishability or poor keeping quality. This is due to the fact that milk is an excellent food, not only for human beings but also for bacteria. Micro-organisms require for their growth foodstuffs, moisture, and warmth. It is not surprising therefore that while milk keeps sweet for some days in cold weather (0–10°C.) it rapidly goes bad or sours in hot weather (20–25°C.). Milk inside the cow's udder is not quite sterile, but contains very few bacteria, usually less

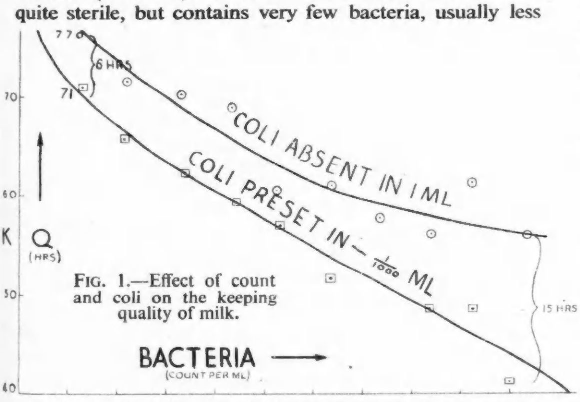


FIG. 1.—Effect of count and coli on the keeping quality of milk.

than 300 per ml. (or c.c.), and these have very little effect on the keeping quality of the milk. In its journey from the udder to the consumer, however, milk is constantly receiving contamination by bacteria from the milkers' hands, pail, churn, creamery plant and finally in the consumer's jug, so that after 24 hours in warm weather the bacterial count may have risen to 10,000,000 or 100,000,000 per ml., and the milk may then smell or taste sour or tainted. The keeping quality of milk is, broadly speaking, inversely proportional to the bacterial count and is specially affected by *B. coli* (Fig. 1). To produce milk of good keeping quality, therefore, precautions must be taken to keep bacterial contamination, and especially *B. coli*, to a minimum and to keep the milk as cool as possible. The two most important factors to watch

TABLE II

Nutritional factor	*Average daily requirement for a 154 lb. adult*	*Amount in 1 quart of milk*	*Proportion of daily requirement in 1 quart*
Protein .	70g.	31g.	½
Calories .	3,000	665	1/5
Calcium .	0·68g.	1·15g.	2
Phosphorus .	1·32g.	0·9g.	½
Iron . .	15 mg.	2—5 mg.	1/5
Vitamin A .	3,000—6,000 I.U.	900—1,800 I.U.	⅓
Vitamin B_1	250—300 I.U.	120 I.U. (raw)	½
Vitamin B_2	1—2 mg.	1—2 mg.	1
Vitamin C .	500 I.U.	0—500* I.U. (raw)	0—1
Vitamin D .	400 I.U. (for children)	5—30 I.U.	—
Nicotinic acid	25 mg.	1—2 mg.	⅛

* Destroyed by light.

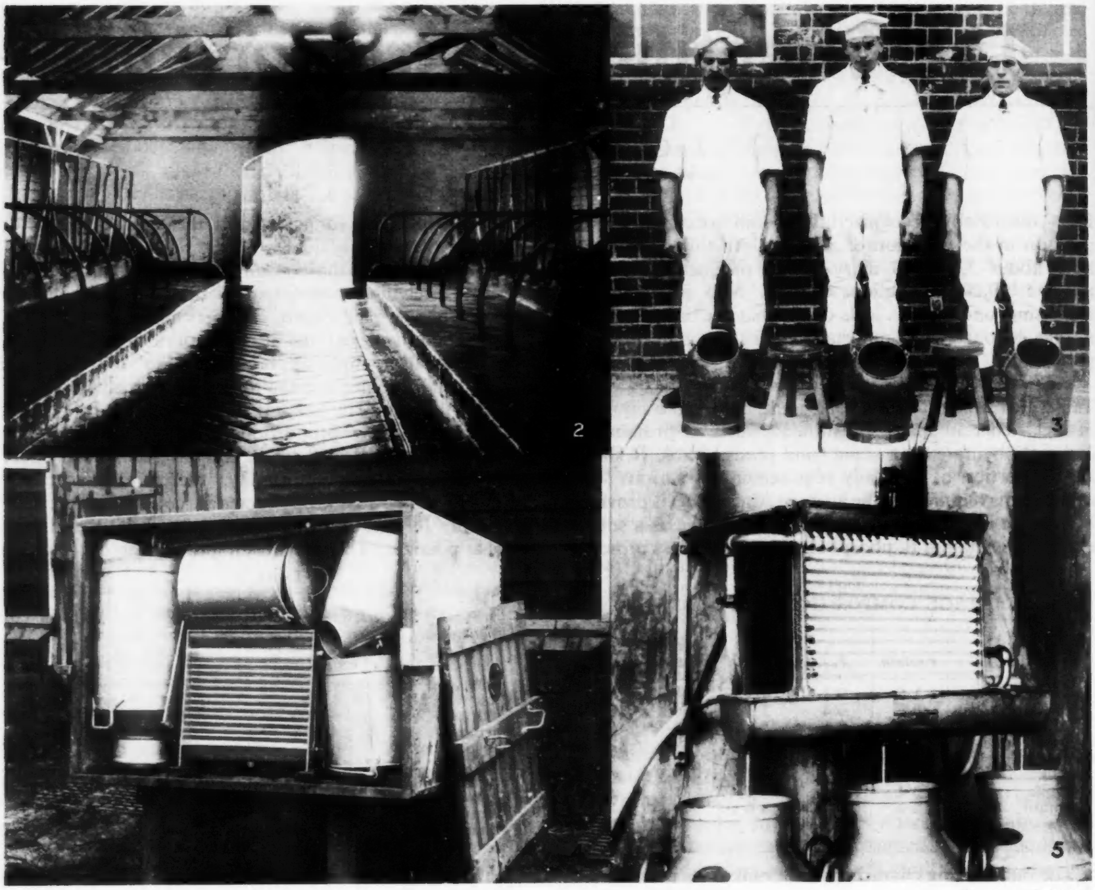
are the sterility of utensils and the temperature of the milk. The tremendous importance of these factors is shown in Table III. The term "clean milk" is used to describe a milk produced under good hygienic and clean conditions; "dirty milk", conversely, indicates a milk produced under bad conditions, transported in unsterile utensils and often not cooled.

The Need for Scientific Control

It might be thought that with compulsory education, public health services, and general commonsense, there

TABLE III

Temperature.		*Plate Count.*			
		After 24 Hours.		*After 48 Hours.*	
°C.	°F.	*Clean Milk.*	*Dirty Milk.*	*Clean Milk.*	*Dirty Milk.*
10	50	11,600	89,000	540,000	1,950,000
13	55	18,800	137,000	3,400,000	38,000,000
16	61	180,000	900,000	28,000,000	168,000,000
20	68	450,000	4,000,000	—	—
30	86	1,400,000,000	14,000,000,000	—	—



Courtesy of N.I.R.D.

FIG. 2.—Reconstructed cow-shed. FIG. 3.—Milkers with clean caps, overalls, stools and covered pails. FIG. 4.—Sterilizing chest containing pails, cooler and churn. FIG. 5.—A typical farm cooler (water section only).

would be no need to worry about the condition of the milk supply, and that losses are negligible and could be overlooked. The truth of the matter is that, in spite of the Milk and Dairies Order 1926, a considerable proportion of our milk supply is unsatisfactory in hygienic quality. The writer has estimated that a third of our producers are good, a third indifferent, and a third poor—and about 8% so bad that their milk imperils the quality of the whole. A small proportion of dirty milk can seriously affect the keeping quality (K.Q.) of a large bulk. In other words the K.Q. of a mixture of 5% bad and 95% good milk is not 95% that of the good milk, but very much nearer that of the bad. This is not difficult to understand when it is realized that under favourable conditions, such as in warm milk, bacteria can multiply every 15 minutes so that one bacterium could in 24 hours theoretically become one million million million million. In actual practice growth retarding factors soon come into play, but not before the milk ceases to have any commercial value. The commercial quality of our milk supply is thus continually threatened by a minority of producers. The farmers, however, are not the only culprits. Many dairies and creameries are equally at fault, and good milk from a farm can easily be ruined by an incompetent dairyman. Both production and distribution therefore need supervision by a competent and impartial authority.

The essentials of satisfactory milk production and distribution may be summarized as follows:

(1) cleanliness in production.
(2) sterility of utensils both on the farm and in the creamery.
(3) adequate cooling by water on the farm and by refrigeration at the creamery.
(4) rapidity of transport.
(5) efficiency of handling at the creamery.

Under war conditions emphasis in agriculture is rightly laid on production, i.e. on the quantitative rather than the qualitative aspect. It is, however, a short-sighted policy to forget quality aspects of milk in war time. It is generally

Courtesy of Jobs' Dairies

FIG. 6.—Sampling milk on the creamery platform.

Courtesy of Midland Counties Dairies

FIG. 7.—The Gerber test for the fat content of milk.

recognized that the hygienic quality of our milk supply has deteriorated in the last few years, and especially in 1940 and 1941. Many factors are concerned in this, the most important being the increased attention paid to arable farming, labour difficulties, and the redirection of dairy advisory staffs to non-dairying activities.

The writer has estimated that at least 5,000,000 gallons were lost in 1941 due to rejections at creameries ("sours") and losses through souring in transit. Probably a further 5,000,000 gallons were lost between the wholesaler and the consumer. As a percentage (about 1%) this figure is not impressive, but it would have given 250,000 children a pint a day for a year! It is, moreover, necessary to probe deeper and to realize that valuable feeding stuffs are being wasted to produce milk that is useless on the market. Further, for every gallon rejected, there are probably 5 or 10 gallons that cause trouble somewhere. The most serious menace, however, is the consequences of a severe heat-wave in war time. Rejections of 5% to 10% are common in heat-waves, and a prolonged heat-wave under present conditions could have disastrous consequences for the milk supply.

The disturbing features of our dairy industry may be summarized as follows:

(1) the poor K.Q. of a proportion of our supplies.
(2) lack of proper equipment on many farms and creameries.
(3) lack of an adequate supply of good water on many farms.
(4) lack of fundamental knowledge on the factors controlling keeping quality.
(5) lack of uniformity in tests and standards.
(6) lack of co-ordination between teaching, advisory and controlling authorities.

Broadly speaking, the same problems are found in all parts of the country.

Producing Good Keeping Quality Milk

There are three essentials—equipment, knowledge, and interest in the work. It is by no means uncommon to see farms well equipped and knowledge available, at least on paper, but because of lack of interest on the part of the milker the job is badly done—quite possibly because one apparently trivial detail is overlooked. The old saying that the strength of the chain is that of the weakest link is nowhere more true than in milk production and handling, and it is for this reason that teachers constantly stress the importance of the mentality of the worker. Although the popular conception is that of the dairymaid, milkers were, before the war, almost entirely men. The war has resulted in the influx of many women to the cow-shed, and milk production is work which is particularly suited to women. On the whole women are cleaner

than men, can undertake routine work better, and give more attention to detail; and it is to be hoped that post-war dairying will see a proportion of women permanently employed in the cow-shed.

To produce clean milk requires an elementary knowledge of bacteriology, particularly the relative significance of different sources of contamination. In the past too much emphasis has been laid on secondary details. Contamination arises through contact, not proximity, and although spacious buildings and elaborate equipment are naturally desirable, it is possible to produce first-class milk under any conditions provided light, water, and steam are available. A good example of a reconstructed cow-shed is shown in Fig. 2, and the good light, concrete floor, dung channels, and broad gangway should be noted. The essential points about the milkers are shown in Fig. 3. They have clean caps and overalls, clean stools, and sterilized narrow-mouthed pails so that the ingress of dust, dung, etc., is reduced to a minimum.

Technique of Good Milking

The hygienic aspects of good milking may be summarized as follows:

(1) keep the hair near and on the udder short.
(2) wash and dry the udders before milking.
(3) draw off 2 streams of fore milk from each quarter (this is richer in bacteria than the rest).
(4) milk dry-handed (i.e. do not wet the hand with milk to "lubricate").
(5) wash the hands before milking each cow.
(6) scrub the stool and sterilize the pails.
(7) remove the milk from the shed as soon as possible, strain through a sterile filter and cool at least to 15°C and lower if possible.

The order of importance of factors in producing clean milk is:

(1) clean and sterile utensils.
efficient cooling.
(2) clean methods and buildings.
(3) freedom from mastitis (udder disease). Mastitis milk is richer in bacteria than milk from healthy udders.

Utensils are conveniently sterilized by steaming for a half-hour in a steam-chest (Fig. 4) and milk is usually cooled by allowing it to run over a surface cooler (Fig. 5). Well water is the best for this purpose, and a brine section or a direct expansion cooler is highly desirable but not always economically possible on small farms. Milk is generally collected in the morning and any trouble is usually associated with the previous evening's milk which is then about 18 hours old. In the absence of proper cooling arrangements, churns should be held in a trough of water sunk in the ground on the north side of the farm buildings. All milk should be in the collecting depot or dairy by 12 noon and there immediately cooled to 3°C (38°F) which virtually stops bacterial growth. (cf. Table III).

Milk Testing

Milk is tested at the creamery for two reasons:

(1) to assess its chemical quality (fat and solids-not-fat).
(2) to assess its bacterial content (i.e. keeping quality).

These two groups of tests are quite distinct and some confusion is caused by vague reference to "milk quality". Specific terms such as "chemical quality" or "solids", and bacterial or hygienic quality should therefore only be used.

The methods in use for fat and solids-not-fat are virtually those used 40 years ago. By contrast the bacteriological methods have undergone constant elaboration and change and so their study affords considerable interest to those interested in milk or scientific control generally.

Sampling

This is a most important procedure. An illustration of a typical method on the creamery platform is given in Fig. 6. For chemical tests all the churns of any one producer may be tipped into the weighing tank (thereby ensuring good mixing) and a portion removed with a 2- or 4-oz. dipper. For bacteriological tests sterile dippers and sample bottles are essential, and the sample must be taken from one or more churns direct to avoid fortuitous contamination. If a sample is to be used both for chemical and bacteriological tests it is best to plunge all churns with a sterile plunger and take a composite sample.

Chemical Tests

The cream or fat in milk is popularly over-rated; the solids-not-fat (i.e. skim milk) are more important from the nutritional point as they contain those constituents, previously mentioned, for which milk is specially important as a food. However, the butter yield is entirely, and cheese yield largely, dependent on the fat content, so it is not surprising that manufacturers have paid particular attention to the fat content of producers' milk, sometimes paying a bonus for high fat values. In the opinion of the writer, however, post-war dairying will see an increase in liquid consumption and a levelling of summer and winter production, with a consequent fall in manufacture in summer. We shall import nearly all our cheese and butter and the summer peak will be largely absorbed in ice-cream manufacture. The public should therefore be educated to realize that the food value of milk lies in the total solids content and that a good "cream line" may be misleading as it depends largely on the size of the fat globules; homogenized milk, which will undoubtedly grow in popularity, has no cream line and yet has a greater "milky" effect in tea. Usually fat and solids-not-fat content vary together, the legal limit being 3% for fat and 8·5% for solids-not-fat, chiefly lactose or milk sugar, protein (casein, albumin and globulin) and salts. A producer can be prosecuted if his milk falls below these limits, but he can clear himself if he can prove that the milk is as it comes from the cow. In cases of suspected adulteration with water, the "freezing point test" is used. This depends on the fact that milk has a constant osmotic pressure corresponding to a freezing point of −0·545°C (average). If the freezing point is above −0·530°C addition of water may be presumed. As the average fat content (Shorthorn) is about 3·7% and the average solids-not-fat content 8·7%, it will be seen that the latter value is nearer the legal limit (8·5%) than the former (3·0%). Any falling-off in chemical quality is thus appreciated first in the solids-not-fat value which, incidentally, is also much more constant than the fat. The common test for the fat content of milk is the Gerber. In this

Courtesy of Midland Counties Dairies

FIG. 8.—Dairy bacteriological laboratory.

Courtesy of Midland Counties Dairies

FIG. 9.—Plating milk for bacterial count.

method the fat is separated by digesting the protein in sulphuric acid and measuring the separated liquid fat volumetrically in the Gerber butyrometer (Fig. 7).

The solids-not-fat may be determined roughly by a simple density measurement of the milk with a hydrometer, called a "lactometer", and the following formula used at 15·5°C:

$$\text{S.N.F.} = \frac{G}{4} + \frac{F}{5} + 0{\cdot}14$$

where G = lactometer degrees (normally 32 as milk has an average sp. g. of 1·032)
and F = fat % by Gerber test.

For accurate work, the total solids are determined gravimetrically, and the solids-not-fat calculated by difference.

Bacteriological Tests

Dairy bacteriology, like all other branches of applied bacteriology, inherited its methods from medical bacteriology, and it has taken many years to throw off the shackles of the medical outlook. The years 1937 and 1942 stand out as milestones in the progress of milk testing and the position is summarised in Table IV on the next page.

It is first necessary to ensure that the reader understands clearly the difference between "clean milk" and "safe milk". The first implies that the milk will keep sweet for a reasonable period, say 36 hours in the consumer's house, and can be controlled by the ordinary routine bacteriological tests described in this article. These tests do not detect disease-producing organisms such as the organisms causing tuberculosis (*Myco. tuberculosis*), typhoid fever (*Eberthella typhosa*), septic sore throat (*Str. pyogenes*), and undulant or "abortus" fever (*Brucella abortus*); and consequently clean milk can be dangerous milk, and dirty milk can be safe milk. Clean milk, however, is less likely to be the cause of such illnesses as summer diarrhœa, which used to be prevalent in young children in hot weather because of the toxins produced by large numbers of staphylococci in milk. The presence of disease-producing organisms in milk can only be detected by specially trained bacteriologists, usually medical bacteriologists, employing special and elaborate tests often involving animal inoculation. Ordinary bacteriological tests in milk are therefore entirely a measure of cleanliness in production and handling, and consequently of keeping quality.

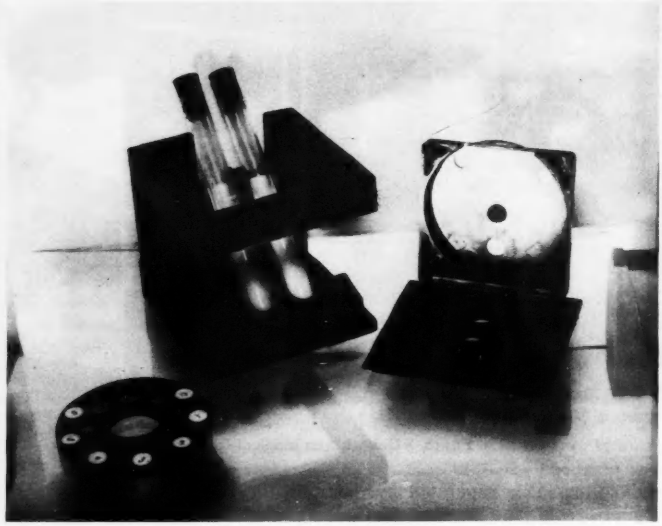
Methods of Estimating Bacteria in Milk

The classical method of estimating numbers of bacteria in materials such as milk is the *plate count*. Dilutions of the milk are prepared by transferring 1 ml. through a series of test tubes containing 9 ml. Ringer (physiological salts solution). Fig. 8 shows a typical dairy bacteriological laboratory with these dilution tubes on the bench. One ml. of each dilution (usually to $\frac{1}{1000}$ ml. milk) are then transferred to Petri dishes (commonly called plates) (Fig. 9) and 10 ml. of a melted agar medium at 45°C added to each plate, the contents mixed, and allowed to harden on the bench. All operations must be carried out aseptically. Plates are then incubated at 37°C for 2 days, removed from the incubator and the colonies (small white or coloured specks in the medium) counted. (Fig. 10). The basis of the test is that each single bacterial cell in the dilution forms one colony, but in practice there are many disturbing factors. Counts may vary considerably according to the nature of the medium, temperature of incubation and even the time of incubation. Other errors (or differences) may arise through the inability of the observer to see tiny ("pin point") colonies. One clump of bacteria in the original milk may form only one colony, or break up and form one hundred. Dirty (high count) milk contains a large proportion of such clumps, often very large, so that this method, while excellent for clean milk, is not so good for dirty milk.

In addition to the agar plate, dilutions are usually added to test tubes containing small inverted (Durham) tubes with a lactose bile salt litmus broth. *B. coli* has the power to ferment lactose in the presence of bile salt and producing gas. "Acid and gas", i.e. bubble in the small tube and the litmus turned red, is regarded as a presumptive positive test for coliform bacteria which are specially harmful to milk, producing taints, and are active souring agents.

Courtesy of Midland Counties Dairies

FIG. 10.—Counting colonies on agar plates.



Courtesy of N.I.R.D.

FIG. 11.—Components of resazurin comparator.

Up to 1937 these tests were universally used and considerable experience and information gained about bacteriological measurements in milk. The chief points may be listed as follows:

(1) the temperature of the milk and time of holding are of predominating importance in any bacteriological test.

(2) so many factors can influence the result that one cannot expect the same accuracy or reproducibility as that obtaining in chemical tests.

(3) all the recognised tests agree in classifying about 90% of the milks tested as good, bad or indifferent. Some milks give rather different results according to the test used.

(4) from a commercial point of view the activity (ability to produce souring) of the bacteria, as well as their numbers, must be considered in assessing the bacteriological quality of a milk.

(5) ordinary standard agar (peptone and meat extract) is an inadequate medium for growing all types of bacteria found in milk. Addition of 1% skim milk gives a satisfactory medium.

(6) the plate count is an extremely valuable test but is expensive and requires at least 48 hours for a result. A quicker, cheaper and simpler test would be a considerable advantage for the bacteriological control of the milk supply.

The Methylene Blue Reduction Test

In 1935 G. S. Wilson and his colleagues had described a modification of the old "reductase test" with greater reproducibility and ease in working and this new methylene blue test was adopted by the Ministry of Health in 1937 for grading raw milks under the Accredited Scheme. This test merely required holding 10 ml. of the milk in a test tube with a little of the dye solution for 4½ hours from May to October and for 5½ hours from November to April. Milks which remained blue were classed as satisfactory; those turning white (in which the bacteria had reduced the dye) failed the test and so were classed as unsatisfactory. The chief difference between the dye test and the plate count was that the former measured *total activity*, whereas the latter measured *total numbers*. A practical advantage was that the new test gave a result in a few hours, whereas the plate count required 2 days.

In 1942 the Ministry of Agriculture tentatively adopted the *resazurin test* for its new National Milk Testing and Advisory Scheme. This may be regarded as a quick form of the methylene blue test. The sequence of tests is outlined in Table IV below.

TABLE IV

SUMMARY OF DEVELOPMENT OF MILK TESTING IN CREAMERIES

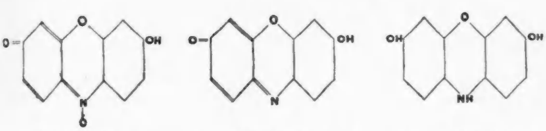
	Before 1937	1937–42	1942
1. Quick platform test	(1) Smell (2) Titratable acidity	(1) Smell (2) Titratable acidity (3) Methylene blue (rare)	(1) Smell (2) Rapid (10 min.) resazurin test
2. Routine grading test	*B category* Sediment pad Titratable acidities	Sediment pad Titratable acidities Methylene blue (few)	Standard (1 hr. basis) resazurin test
	A category Plate count and coli	Methylene blue (most)	

The Resazurin Test

First introduced in 1928 by two German workers, this test has been chiefly developed in this country by Thomas and his colleagues at Aberystwyth, and by the writer and his colleagues at Reading. The resazurin and methylene blue tests are both dye reduction tests and therefore fundamentally the same. Resazurin reduction is a little more complicated than that of methylene blue as there are two stages of reduction—an irreversible change from blue *resazurin* to pink *resorufin*, and a reversible change from pink *resorufin* to colourless *dihydroresorufin*. The chemistry of these changes is illustrated in Table V. Besides being

TABLE V

REDUCTION ⟶



RESAZURIN (Blue) ⟶ (Irreversible) RESORUFIN (Pink) ⇌ (Reversible) DIHYDRO-RESORUFIN Colourless)

indicators of reduction caused by the chemical reactions taking place in the bacterial cell, these substances are also indicators of acidity (pH) but as they change at pH 6 or less, and milk has a pH of about 6·5, this acidity effect is only appreciable in very sour milk which quickly reduces the dyes. The second or pink—white stage is exactly analogous to the reaction methylene blue—methylene white, but requires a longer time in milk. The technique of the resazurin test is identical with that of the methylene blue test except that the tubes are held at 37·5°C for only 1 hour (moderate atmospheric temperatures) and the colour of the milk plus dye is then matched in the resazurin comparator. This consists of a bakelite disc with small pieces of coloured glass varying in tint from blue (disc 6) through purple to full pink (disc 1) and colourless (disc 0). The disc is held in a frame over a control tube and revolved until matching is obtained. Intermediate values are recorded as ½—i.e. 3½ is between 3 and 4. The components of the comparator are shown in Fig. 11 and the method of

TABLE VI

INTERPRETATION OF STANDARD 1 HOUR RESAZURIN TEST

(MODERATE TEMPERATURES)

Disc No.	*Colour.*	*Bacteriological Quality.*	*Resazurin*	*Resorufin*	*Dihydroresorufin*
6	Blue	Excellent	100	0	0
5	Lilac	Very good	80	20	0
4	Mauve	Good	60	40	0
3	Pink-mauve	Fair	40	60	0
2	Mauve-pink	Poor	20	80	0
1	Pink	Bad	0	(100)	(0)
0	White	Very bad	0	0	100

The figures under the dyestuffs represents % concentrations in relation to the original resazurin.

Courtesy of N.I.R.D.

FIG. 12.—Using the resazurin comparator.

using in Fig. 12. The quality of milk in relation to disc numbers, etc., is indicated in Table VI, and the advantages of the resazurin test are briefly summarized in Table VII.

TABLE VII

ADVANTAGES OF THE RESAZURIN TEST WHEN COMPARED WITH THE METHYLENE BLUE TEST FOR MILK CONTROL WORK

1. **Adaptability and flexibility.**—The resazurin test can be used as a rapid test on the platform, for routine grading, in combination with the rennet test, for testing the sterility of churns, etc. Both the end-point (disc reading) and the time of incubation can be varied at will for the purpose of setting standards, and this fact endows the test with considerable flexibility.
2. **Simplicity.**—Only one reading, e.g. after 1 hour, is required, compared with from 6 to 12 readings with the methylene blue test extending up to 6 hours.
3. **Testing on the same day as sampling.**—The standard test on p.m. and mixed samples can be carried out at 3 p.m. on the day of sampling, thus avoiding overnight refrigeration, which has a variable effect on the sample.
4. **Sensitivity to weakly reducing organisms.**—A milk rich in only weakly reducing organisms usually affects resazurin but may fail to reduce methylene blue for many hours.
5. **Sensitivity to cells (mastitis, etc.).**—A high count of cells, whether due to mastitis, colostrum or late lactation milk, is usually associated with other abnormalities and is disadvantageous for many reasons. Resazurin, but not methylene blue, is sensitive to high cell counts in aged milks.
6. **Relation of result to initial flora.**—In a short time test the result is more likely to bear a closer relation to the initial flora than in a longer test.
7. **Possible contamination in sampling and testing.**—This will naturally be of less significance in a short test.
8. **Use as a "methylene blue test".**—By prolonging the test to complete reduction it becomes in effect a methylene blue test of slightly longer time.
9. **Uniformity.**—The advantage of standardization on one test is obvious.

(Dr. Davis' article will be concluded in the April number.)

Photomicrograph of a flea (*Xenop syllacheopsis*). This species is the chief vector of the Bubonic Plague, transmitting the disease from rat to man. Photographed on infra-red plate and filter. Magnification × 60.

The Flea

D. ROSENTHAL

It has often been stated that the more insignificant Life is, the more destructive is it liable to prove. Nothing could be truer of that minute insect, the flea.

This tiny creature has, since the beginnings of civilization, been the cause of frequent outbreaks of disease, leaving death in its wake. So awe-striking was the way in which this flea-borne disease travelled, that it has been named "The Plague".

From the Great Plague, in the days of Justinian in the sixth century, to the middle of the seventeenth century epidemics of varying severity occurred throughout Europe. The most disastrous was the "Black Death" of the fourteenth century which spread over Europe and destroyed over 25 per cent of the population. In the seventeenth century the "Great Plague" of London caused the death of 70,000 people within the city. At this time, an observant person would have probably noticed the unusual number of dead rats lying about. But in any case, he would have failed to connect this fact with his tiny bedfellows who caused him to spend a restless night tossing and turning and scratching.

It was not until 1894 that two scientists, working independently (the Frenchman, Yersin; and the Japanese, Kitasato) found the bacterium that caused this frightful disease—the *Bacillus pestis*. Dissecting dozens of dead rats, they found an organism identical with that in the bodies of the plague's victims. It remained, however, for Liston and other workers in 1905 to prove that the vector of the scourge was none other than the flea.

The plague is, in the first instance, a disease peculiar to rodents. In addition to the rat, other carriers include the ground squirrel in California, the marmot in Tibet, the gerbil in South Africa.

When a flea feeds on an infected rat it imbibes some of the bacilli from the bloodstream. Eventually the rat dies from the plague; then, when the body has grown cold, the flea seeks a new host. If a human is in the vicinity the flea will proceed straight to him.

Meanwhile the bacilli have increased tremendously in number in the flea's stomach, so that its gut becomes blocked

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with millions of the germs. When next it takes a feed from man, the unfortunate creature is unable to swallow the blood; thus—still more unfortunately for its host—it regurgitates its meal carrying some of the plague bacilli with it. Then, the vicious circle is complete.

There are two types of plague. One is the bubonic plague, in which buboes (inflamed lymphatic glands) are present. An abscess may form at the site of the swelling and the condition remain local, in which case the patient may recover; or general septicaemia may set in which results in the death of the patient.

The second and more deadly form is the pneumonic plague, where the victim's lungs become choked with bacilli, and each time he coughs millions of germs are released into the atmosphere. Nearly every case of this type dies.

No efficacious serum has yet been produced, but a prophylactic vaccine has been used with fair success as a preventive agent in India and the East, where plague is still fairly prevalent.

And now a few words about the flea's life history. The female flea lays a batch of pearly-white eggs in its host's bedding. In from four to eight days a whitish coloured larva emerges. This feeds on the organic materials in the debris (e.g., the host's epidermal scales, the parents' faeces, etc.). The larva is fully grown in approximately fourteen days. It now proceeds to spin for itself a silken cocoon, using the debris in its surroundings. Having completed this, it may remain within as a resting larva from three days to several weeks, after which time it pupates. It remains in this state for a varying period of time, usually about ten days, when it finally emerges as an adult.

THE STOREHOUSE OF THE SEA—*contd. from p. 78*

in the order calcium, strontium, barium, is about 4000:100:1. The temperature of the water may also have an effect on the presence of strontium instead of, or together with, calcium in shells. In very cold waters strontium may replace calcium and there is a report of radiolarian from the Antarctic whose shell is composed almost entirely of strontium carbonate. In other shells both are present in much the same proportion as that in which they occur in sea-water.

The sea is the greatest potential source of raw materials: it contains traces of every element ready to hand so that marine plants or animals can adapt them to their purpose. There is true symbiosis between animal, vegetable and mineral. Our approach to this subject has been from the mineral aspect, to ascertain what minerals can be economically won from the sea in competition with land sources of the same materials deposited in bygone geological ages. The sea gives us a great quantity of food in fish of all kinds: the study of these is an important branch of science, for it is certain that in times to come we shall not only require more fish but make better use of the catch. The great medicinal value of the liver oils as a source of vitamins is an example. Less use is so far made of seaweeds, but here also research is beginning to show that novel and perhaps useful and valuable substances are present, and before long there will have been worked out methods of harvesting the weed and fabricating diverse products from it.

The Night Sky in April

M. DAVIDSON D.Sc., F.R.A.S.

New moon occurs on April 4d. 21h. 53m., U.T., and full moon on April 20d. 11h. 11m. The following conjunctions take place during the month:

April				
7d. 11h.	Venus in conjunction with moon,			Venus 6°N.
9d. 01h.	Saturn	,,	,,	Saturn 3°N.
12d. 05h.	Jupiter	,,	,,	Jupiter 4°N.
29d. 17h.	Mars	,,	,,	Mars 0·1°S.

Occultations.—The following occultation of stars brighter than magnitude 6 occur, the times referring to Greenwich:

April 16d. 22h. 16m.	χ Leo	D
18d. 24h. 55·3m.	γ Vir.	D
22h. 43·2m.	..	R
25d. 3h. 42·6m.	21 Sgr.	R

The Planets.—Mercury is in superior conjunction on April 4th and reaches its greatest eastern elongation on April 30th. At this time the planet sets about 2 hours after the sun in the latitude of Greenwich and is favourably placed for observation. It can be seen by those who know its position and are equipped with an equatorial mounting.

Venus is an evening star and at the end of the month sets 3 hours after the sun. The planet will be in conjunction with Uranus on April 18d. 04h., and with Saturn on April 25d. 04h.

Mars souths at 8h. 34m. about the middle of the month but is too low to be favourably observed in northern latitudes.

Jupiter in the constellation of Gemini souths at 17h. 42m. in the middle of the month and is well placed for observation in the earlier part of the night.

Saturn souths at 15h. in the middle of the month and sets at 23h. The planet is disappearing in the west.

The Scientific Worker

THE relationship of the scientific worker to his colleagues in other spheres of work has perhaps never been put so clearly than by Sir Robert Watson-Watt, F.R.S. He says:

"The scientific worker *is* the plain man. He is a proud member of the labour force; a craftsman exceptionally happy in his craft, with an unshakable belief in the potency of his craft, with a burning enthusiasm for its full use in the service of the plain man. He is in the labour force with his fellow-craftsmen; he is not wholly of it. He is not infrequently qualifying for admission to the sphere of management, as are many other members of the labour force. The proportion of administrative and policy-making ability is probably no higher and probably no lower in the scientifically trained group than in any other representative group in the community. It is perhaps a little higher in general, because of the objectivity and critical faculty which are of the essence of the scientific method; perhaps a little lower in particular, because of an occasional excess of zeal, because of the hobby-interest which is at once a main reward and an inherent unbalancing factor in his way of life."

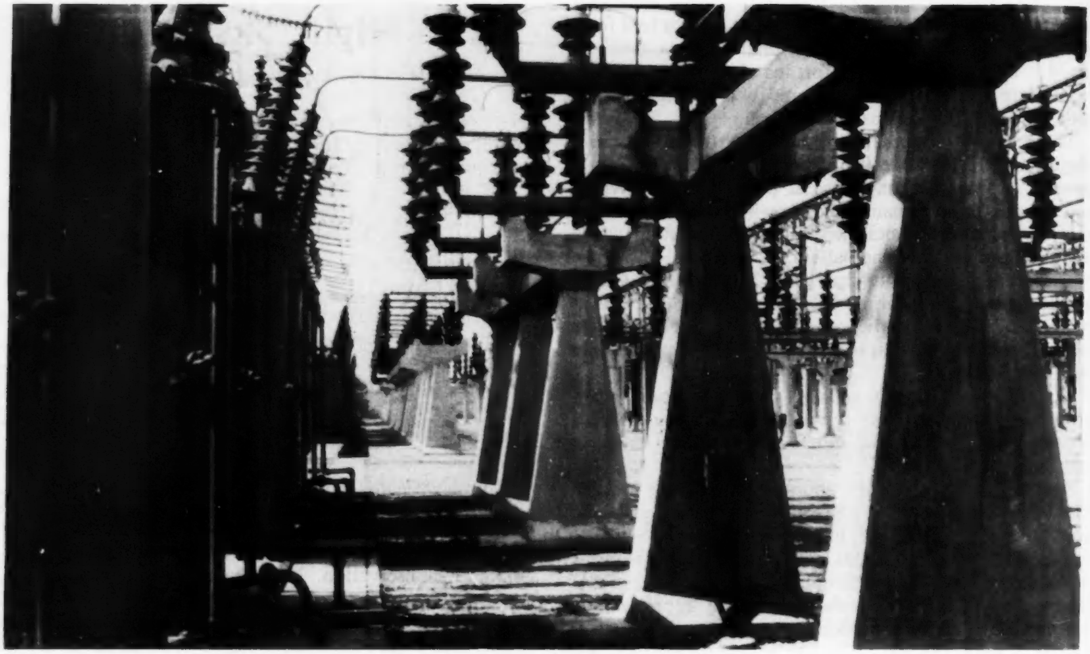

FIG. 1—An Outdoor Sub-station

The Grid

A. G. H. DENT, A.M.I.E.E., F.R.Econ.S.

We may treat the origin, the functions, and the work of the Grid in many ways. It represents a solution to various technical and economic problems in the public utility field and is a natural outcome of advances in the application of electrical engineering science to the power needs of the community.

Before discussing the factors which determined this power co-ordinating plan—for this is the simplest way of describing the Grid scheme—we should make clear the economic character of the public utility enterprise. To regard this specific class of enterprise in the same light as a manufacturing industry leads to a false basis of appraisal or criticism, and it is desirable to understand both the advantages and the limitations of the electricity supply industry before examining the problems which were solved by the creation of the Grid.

Briefly, the public utility is an undertaking "affected with a public interest". Its main characteristics are: very large capital investment and costs, with low turnover; high ratio of overhead to prime costs, subject to increasing returns up to the time of the full use of its capital investment; a fixed market (local or regional distribution); high degree of monopoly; means of conveying service to consumer, inflexible, involving large fixed costs; high degree of necessity as there is no exact substitute.

The public utility operates under special licence from the State and provides a uniform service. It tends to charge prices for its product which vary with class of use because of the limitations imposed on its structure by the factors of very high overhead costs and a fixed market of supply. It follows that overhead costs cannot be distributed with absolute equity and accuracy over the different units generated and sold.

Two basic obligations are present with great force in the electricity supply industry—the need for large production units, for reserve capacity, and for a substantial distribution network; and the need to supply any quantity of electrical energy to any consumer on demand, although this energy cannot be stored in advance to anticipate such demands.

Considering the consequences of the latter obligation, we see that the plant capacity of a specific, local generating station must be sufficient to meet the maximum demand anticipated during the year, or preferably during several years ahead, since it is not practicable to add new generating capacity in small pieces at small intervals.

If we consult a typical load curve, we can see when the peak period arises, we can see its approximate ratio to average demand, and we can see the large amount of plant which is not in use during the periods of small demand

With local generation, we can visualize a series of generation stations, of different size, generated voltage, and frequency of supply, all isolated from one another and all bearing the burden of unused spare capacity for many months of the year. This burden, inevitably, must appear in total costs and emerge in prices charged to the consumer.

We are describing, broadly, the situation in Great Britain before the Grid scheme. At that time, it is estimated that the amount of spare generating plant which had to be carried equalled about 80% of the actual load. It was apparent that, if the generating plants could be interconnected, one plant could help out another. Thus the Grid scheme secured a pooling of the risks of supply breakdowns at the times of peak load, an important protection for the supply engineer. In addition, the reduction in spare plant achieved through interconnection has been considerable.

Technical Advances

We should now note the historic forces, tending towards co-ordination. Technical advances during the last hundred or so years have extended the applications of electricity and the demand for its use. In 1831, Michael Faraday's discovery of electro-magnetic induction made the dynamo possible: in 1879, the work of Swann and of Edison made the electric lamp a practical device: a few years later Ferranti equipped the Deptford generating station with comparatively high voltage alternating current generators, and transmission became feasible with the development of the transformer. Soon, came the revolutionary steam turbine of Sir Charles Parsons and a period of great development of A.C. distribution. Electricity was taking its proper place as a unique source of mobile and flexible power.

But, lack of co-ordination fettered its full use. Legislation had failed to liberate electricity from customary thought. The various owners of supply undertakings, local authority and private enterprise, were engaged in unprofitable rivalry about the respective merits and demerits of forms of ownership. It required the impact of a war to secure the proper use of generating resources for the community.

The power demands of the Great War for the production of munitions exposed the weaknesses of the electricity supply industry. By 1916, the threatened shortage of generating plant caused the Board of Trade to urge regional co-ordination and the linking up of systems in order to save coal. The obstacles of varying pressures and frequencies of supply and the lack of co-operation between local authorities and private companies prevented anything useful being done.

The 1917 coal shortage forced the Government to appoint investigating Committees to advise on the reorganization of the industry. The 1918 Committee, under Sir Archibald Williamson, proposed to concentrate the supply of electricity in sixteen districts, with one authority in each district, as an improvement on the 600 odd supply areas in existence. A board of Electricity Commissioners was advocated, having full powers over the industry. These powers were to include: preventing the extension of uneconomic generating stations; handing over to a new Electricity Authority, in each of the sixteen districts, the work of generation, transmission, and main distribution; standardizing frequency and voltage; and deciding the form of authority to be created. New and highly efficient generating stations of large capacity were to be built, operating through a comprehensive distributing system, to supply electricity at low cost for industrial uses.

These proposals were opposed and modified in Parliament, but the consequent Electricity Supply Act of 1919 established the Electricity Commission with certain powers of supervision and regulation over the industry. It is a planning, licensing, and judicial body, but, in 1919, it had no powers to enforce regional co-ordination among the various supply undertakings for the creation of new and larger Authorities. Very few of these Joint Electricity Authorities were created.

However, the Commission did possess powers to examine the whole problem of reorganization on a national scale. So, in 1925, the historic Weir Committee was appointed. This Committee, in its recommendations, distinguished between the functions of production and of distribution. Recognizing that production was more easily handled than distribution, it advocated the creation of a new body, the Central Electricity Board, whose task would be the co-ordination of the production of electricity throughout Great Britain. It would reduce the cost of generation by concentrating production in comparatively few, highly-efficient stations of large size. These stations would be interlinked by a main transmission system, working at 132,000 volts.

It was thought that 58 stations would be adequate, 15 of these to be new, while some 432 stations were to be closed down. The excessive capacity of spare plant in existence would be reduced as a result of inter-connection, and maximum efficiency would be obtained by allocating the base load to the more efficient stations and leaving the peak load to be carried by the remainder. For the complete interconnection of stations to be a practical proposition it was essential for frequency to be standardized, and the Electricity Commissioners proposed that the standard should be 50 cycles per second.

These proposals were embodied in the Electricity Supply Act of 1926. We have arrived at the birth of the Grid, ninety-five years after Faraday's discovery made possible the generation of electricity.

The Board is a technical and operating body. While it has the duty of concentrating production in a limited number of stations, known as "Selected Stations" and to control their operations, these stations remain the property of individual supply undertakings. However, these undertakings must run their stations in accordance with the Board's instructions. It is important to note that the Board does not own the stations and has no control over the supply of electricity to the public as ultimate consumer.

The Construction of the Grid

The construction of the Grid was carried out methodically and swiftly. Great Britain was divided into areas, originally nine in number, for which schemes were prepared by the Electricity Commission. These areas were: Central Scotland, South Scotland, North-east England, North-west England and North Wales, Mid-east England,

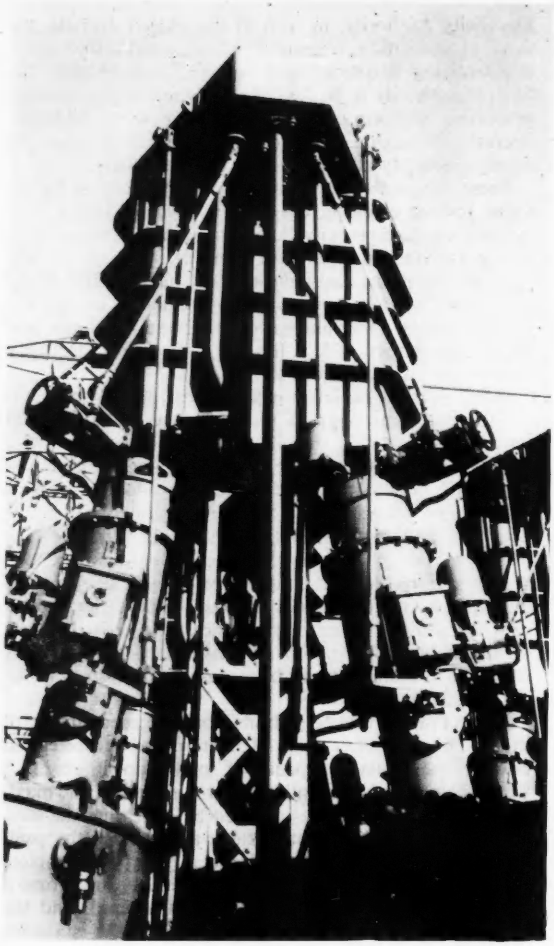

FIG. 2.—Metal-clad Out-door Switch Gear.

Central England, East England, South-east England, and South-west England and South Wales. No scheme was prepared for North Scotland.

Since the original planning, two groups of areas have been combined for operation purposes: South-east England and East England in the south, and Central and South Scotland in the north.

The Board received the schemes from the Commissioners and had to discuss various features with interests affected, such as local authorities, supply undertakings, landowners, and others. The study and adoption of technical projects commenced in April, 1927, and was not finished until August, 1931. The first scheme was for the Central Scotland area, submitted on March 24th, 1927, and adopted by the Board three months later. By January, 1933, normal trading with supply undertakings had begun in two areas, with centralized control of generation. Construction began early in 1928. The last tower of the main transmission system was erected in Hampshire in September, 1933.

The main lines operate at 132,000 volts and have a nominal capacity of 50,000 kilowatts per circuit. In each area, transforming and switching stations have been built for inter-connection. Each area also possesses its Central Control Room, where the power system of the area is regulated. The extent of the Grid system can be realized from the latest published figures;* for December 31st, 1939. These show some 4,430 miles of transmission line, of which some 3,039 are primary lines operating at 132,000 volts, and the remainder secondary lines operating at 66,000 volts and lower voltages. The transforming and switching stations number 307 at this date, having a total capacity of 10,971,000 k.V.A. (kilo-volt-ampères).

The construction of the Grid was a great engineering enterprise. It provided considerable work for a diversity of manufacturing firms; it gave some of them new and difficult technical problems to solve. For instance, in the cable field, high tension cables required for connections to selected stations had to operate at 132,000 volts over some 23½ route miles. The cable makers met the challenge of this demand, although at the time the Central Electricity Board was created there was almost no experience of cables to work at this voltage, or even at 66,000 volts. In the insulation field, overhead line transmission has to meet conditions of fog and of industrial pollution, making necessary the development of special types of insulator for various sections of line.

A calculation has been made that the Grid contracts represented about 240 million man-hours of work, roughly equivalent to 20,000 men fully employed for five years. The industries beneficially affected included iron and steel, coal, electrical engineering, pottery, cement, building, and so on. About 150,000 tons of steel were required and 12,000 tons of aluminium.

Spectacular crossings of navigable rivers were made by main transmission lines, spanning the Clyde, the Forth, the Ribble, and the Thames. The highest of these crossings is the Thames crossing, near Woolwich, where the towers are 487 feet high, carrying the 132,000 volt lines over a 3,000 feet span.

A number of the selected stations were designed for outputs between 200,000 and 350,000 kilowatts. Since the construction of the original Grid programme additional generating capacity has been required to meet the growth of load. This has taken place under new conditions in which the co-ordination of generating plant development has become possible.

Utilizing Water-power Resources

We should mention an interesting development made possible by the Grid system, namely the utilization of the water-power resources of the Galloway mountains. Before the building of the national transmission scheme, the water-power potential could not be used because there was no means of consuming the energy generated. Galloway is, for the most part, a wild and poorly populated area. The Grid scheme, however, provided links from Galloway to Glasgow and Lancashire enabling the power generated to be transmitted for industrial uses in both England and Scotland. A further result of this development

* Garcke's *Manual of Electrical Undertakings*, Vol. 43, 1940/41.

was the availability, regionally and locally, of power at economic rates for the growth of local industries, agricultural application, and the electrification of villages and townships.

The catchment area is about 400 miles in extent, and the chief sources of power are Loch Doon, Loch Ken, and Clatteringshaws Loch, in the north of Kirkcudbright Stewartry. There are two other water-power schemes in operation: the Grampian scheme feeding into the Grid system at Abernethy in Central Scotland, and the North Wales hydro-electric system, feeding in at Crewe.

The construction of the Grid not only interconnected the most efficient stations; it provided some 300 Grid points from which to give supplies to electricity undertakings. While there existed various transmission systems in different parts of the country, these systems were, for the most part, isolated from one another; and they left untouched a number of areas capable of development.

Planned Use of Generating Stations

At this point, we should examine the method of planning the use of the selected stations and the system of control. The division of generating stations covers base load, two-shift, and peak load classes. The base load stations do most of the work. These are the most modern and efficient plants which run continuously for twenty-four hours a day on practically full load. This operating condition gives the high load factor position producing the maximum economies of generation. Much of the output of these stations may be used by the undertakings owning them for their own systems, but the balance is exported to the Grid for the use of other supply undertakings.

The term "load factor" measures the proportion of the available capacity which is actually used and is expressed as the ratio between the total units used (kilowatt-hours) and the total units which would have been used if the maximum demand on the plant (kilowatts) had been maintained during the year. The formula is, hence, giving a percentage:

$$\text{Load Factor} = \frac{\text{kWH used in year} \times 100}{\text{kW of max. demand} \times 8760}$$

(8760 being the number of hours in a year).

The two-shift stations are, as a rule, smaller than the base load stations, and may be operated for about two-thirds of the maximum time. They are normally shut down during the nightly low load period, during the week-ends and, in some instances, during the summer. These stations are available to supply the system if an interruption occurs in the supply from base load stations.

The peak load stations are usually only needed to come in to meet peak demands on winter days. Their chief function is to cope with sudden, high demands caused by such factors as extreme cold and dense fog. Without these stations, the base load and the two-shift stations would require wasteful quantities of spare plant.

To operate these groups of stations efficiently some central control is needed, so that each "Scheme Area" has a highly equipped Control Room, connected to all the generating stations and Grid points in the area, by private telephone lines. As a rule, a programme of operations is set out for the majority of the stations, but control engineers develop, through experience, a technique which uses all available stations most efficiently. These points have been rightly called "the nerve centres" of the Central Electricity Board's operating organization. They are connected to generating stations by means of an elaborate scheme of intercommunication over special circuits rented from the Post Office.

FIG. 3.—Tower into Sky.

It should be mentioned that the advance in electrical communication technique, as represented by the carrier current system, enables a number of messages or signals to be transmitted simultaneously over the same pair of wires, these messages being filtered out at the receiving end of the line, in terms of their different frequencies.

Using a combination of dials, light signals and telephones, the Control Room staff are able to watch the changing demand through the various switching stations, and to record the import and export of electrical energy at the generating stations. Detailed records are always available for checking the efficiency of operation. Panels give

such important data as load figures and automatic indication of switching operations. Messages are transmitted to the staff at distant generating stations, telling them to pick up load or to drop it as circumstances require. Another valuable aspect of control is the technique of anticipating load changes, so as to prepare for them in advance. In developing this technique, records are analysed to find out variations in load and their causes. Naturally, weather reports form a useful item in basic forecasting data. Again, changes in demand caused by broadcasting are noted: special speeches or highly popular broadcasters are known to produce increases in load.

It will be evident that, with methods of this elaborate kind, it becomes possible to create a flexible and efficient system of control throughout the entire system of power supply. The most efficient stations are employed where they are most wanted. Using the stations of large capacity and high efficiency, important reductions in fuel consumption per unit generated are achieved. (This applies to normal conditions.)

Naturally, operating economies of some size result from the effective use of a national power network, regionally regulated in this way. But, apart from the fact of co-ordination and a new operating technique, there are other advantages. It is now practicable to relate production capacity to demand efficiently so that a condition of economic use of plant—and plant investment—has been attained. The reserve plant problem has been dealt with. It is estimated that during 1931 more than 45% of the power plant in generating stations throughout the country was in reserve. Since the inception of the Grid scheme, this figure has been progressively reduced.

Concerning capital investment, the savings have, evidently, been great. Authorities estimated savings in generating plant, due directly to the construction of the Grid, to be about £11,500,000 by the end of 1935, and calculated that the initial cost of the Grid—about £27,000,000—had been saved by the end of 1937. It should be pointed out that this saving is made by the entire industry and must be finally reflected in the levels of charges to consumers, although it is not possible to make a definite calculation on this item.

Operating policy has to take into account the factors of wide seasonal and hourly variations in the demand for electricity in the different Scheme Areas and within these areas. Commercial efficiency determines the amount of work done by the selected stations. Their capital charges and other overhead charges, plus a high proportion of such operating costs as repairs and maintenance, salaries and wages, etc., remain constant, irrespective of the way in which demand is distributed over them. Apart from these items, there is running costs of which the largest part is fuel cost. This item depends upon the number of units generated at each station, so that the ideal economic operating programme will give the maximum practical production to the stations which have the lowest running cost. This is conditioned by the need for arranging regular overhauls of station plant.

The extent to which the Central Electricity Board has been able to unify and co-ordinate the generation and main transmission of electrical energy can be seen from the last published Report of this body, for the year ending December 31st, 1938. To quote: "Before the passing of the 1926 Act, the electricity made available for supply by the distributing undertakers was produced at some 500 generating stations . . . The Board in 1938 had the direction of the operation of 136 selected stations and, by agreement, controlled 35 non-selected stations which for a time could usefully be operated in conjunction with the Grid.

"At the end of the year, 217 of the 560 distributing undertakings in the area in which the Board were trading were being supplied directly by the Board, and a further 300 were connected to the Grid through the systems of undertakers, who, in turn, were receiving their supplies from the Board . . . Most of the others were small undertakings remote from the Grid system and were supplied from local stations, many of which were hydro-electric, or from non-statutory sources.

"During the year 97·2% of the electricity supplied by the distributing undertakers in the country (excluding North Scotland) was produced at stations which, by the end of the year, were generating for the Board.

"Interconnection through the Grid made it possible so to control the operation of the 171 generating stations under the direction of the Board that only 30 ran for the full year. . . . Fourteen of the most economical stations supplied 50% of the total units generated for the Board."

The Report gives the total generating capacity of the plant installed in selected stations as 8,264,160 kilowatts, with an output for 1938 of 24,376 million units, the area having the highest output being South-east England.

Trading Arrangements

The total charges due to the construction of the Grid have to be secured by the Board from the sale of electricity in bulk from its transmission system to the various electricity supply undertakings. As the Board is a non-profit-making concern, the aim is to fix tariffs that will just cover the total costs, and in order to make the terms as advantageous as possible to development, the first tariff period was fixed at ten years. The determination of the tariffs was such that deficits were budgeted for in the early years of operation, to be balanced by surpluses in the later years realizable from the high rate of expansion of electricity demands.

Trading arrangements are such that the Board's supplies of electricity are normally charged at the Grid Tariff for a specific area. The owner of a selected station, however, has the right to re-purchase as much of the electrical energy produced at his station, as he may need, at an alternative price. This is the cost of production (adjusted according to the load factor and power factor of the supply) with the addition of a proper proportion of the Board's expenses in providing, maintaining and operating the Grid.

Further, a provision of the Act states that the owner of any existing selected station shall not pay more for his total supply than the cost which (in the judgment of the Electricity Commissioners) he would have incurred in generating a similar supply under conditions of independent operation. This cost includes the provision and maintenance of adequate spare plant, since this item would have been essential had there been no Grid scheme.

The Grid Tariffs do not vary much from one area to another. Fundamentally, they consist of a basic charge per kilowatt of demand, which varies from £3 10s. 0d. to

£3 7s. 6d., plus a running charge per unit which varies from ·186d. to ·24d. There is a progressive reduction in the kilowatt charge as the maximum demand of an undertaking increases beyond its basic demand, which is normally that recorded in 1932. The running charge is varied with the price of coal; the fixed charge is adjusted according to power factor, and to meet changes in local taxation.

Electricity supply undertakings which do not own generating stations and whose systems are directly connected to the Grid, buy all their electrical energy requirements at Board tariff rates.

There is one variation from customary supply practice which should be mentioned, as it has an important bearing on electrical development. Nine years after the passing of the 1926 Act, a new Act was passed which followed up a proposal of the Weir Committee on railway electrification. The 1935 Act empowered the Board, within certain limits, to supply directly any railway company for traction purposes. By permitting the Board to negotiate direct with these companies for a supply at a number of points, the new legislation assisted materially the advance of railway electrification.

Mention should be made of an important part of the functions carried out by the Central Electricity Board, under the 1926 Act: the standardization of frequency. It will be realized that the benefits of national interconnection would be seriously upset if different areas were to have different frequencies of supply. As the industry has grown, certain large supply zones have been developed on a non-standard basis. The standard frequency of supply adopted by the Grid system is 50 cycles per second. In various areas electricity has been generated and distributed at such frequencies as 25 cycles and at 40 cycles per second.

The work of standardization involved the task of installing between 1,500,000 and 2,000,000 h.p. of new electric motors on the premises of consumers, notably in the industries of engineering, shipbuilding and iron and steel.

The cost of this necessary work is a charge levied on the whole electricity supply industry, since it is a national undertaking to benefit the industry as a whole. These charges are collected by the Electricity Commission, the actual levy being based on units sold and transmitted to the Board.

Consideration of the subject of railway electrification carries us forward to the utilization of electricity through the distribution system. It has been shown, in this article, how the generation of electrical energy came to be coordinated and put under one central control. We have seen the work accomplished in this technical and economic achievement. We have seen how the plan has been carried out.

The distribution of electricity remains in the hands of a large number of supply undertakings of different types of ownership, different size of area and different potentialities of demand. This condition has been criticized by many authorities. Reports have been made which advocate various reforms, but no action has been taken. Evidently, after the war, some decisions will have to be made by those responsible as to the future character of electricity distribution.

The Grid plan has solved the generation problem: a complementary plan is needed to complete this work. The problems of electricity distribution are too many and too complex to discuss in this article. Perhaps we should be content with a simple realization of the potentialities of a fully co-ordinated electricity supply industry. For electricity is not merely a form of energy: it is unique in its capacity to serve as an instrument of social and economic planning; to raise the standards of living. To quote an important study by P.E.P.:

"Electricity is mobile power, and as such, has more affinity with transport than other forms of power such as gas, coal and oil. Alone among these sources of energy, it can be used to change the present regional economic balance of the country through the widespread availability of cheap power for industrial purposes. Until this power had developed technically, the possibilities of control of industrial congestion and of other factors, such as smoke, conditions of labour, or even the design of industrial buildings could not be realized . . . Decentralization of electrified plants is one thing, however; planned decentralization is another. . . As far as economic planning is concerned, the influence of electricity in regional planning should be positive, urging planners beyond the early stage of mere restrictions upon the siting of industry towards the coming stage of constructive co-operation between industries and government, based on the economic character and needs of different areas. Mobile power is an instrument of planning, waiting to be used effectively."

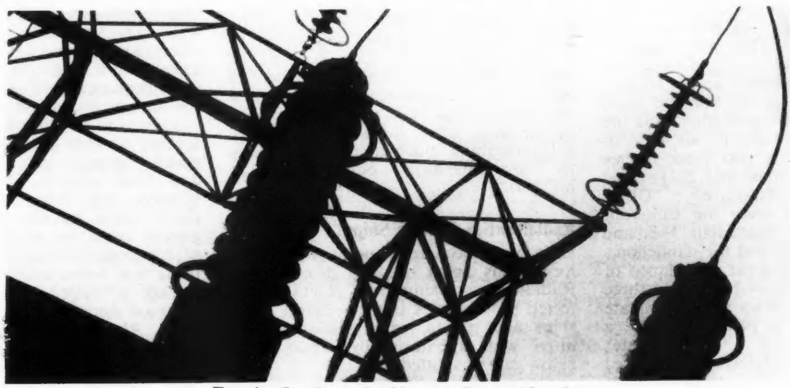

FIG. 4.—Insulator Bushing on Surge Absorbers

Far and Near

Scientists Abroad

SCIENTISTS are among the lecturers sent abroad recently by the British Council. The Astronomer Royal, Dr. Spencer Jones, is visiting Turkey, Palestine and Egypt, while Mr. R. A. McCance, the biochemist and authority on nutrition, has started on a lecture tour of Spain and Portugal. Dr. Cyril D. Darlington, director of the John Innes Horticultural Institution, has just returned from Sweden with interesting details about war-time plant-breeding experiments in that country. Prof. Joseph Needham, reader in biochemistry at Cambridge, is in Chungking. Another scientist who is out of the country is Prof. J. D. Bernal, scientific adviser to Lord Louis Mountbatten of Combined Operations. He is reported to be in North Africa. He is, however, expected to be back in time for the Institute of Physics Conference at Cambridge in April.

Scientists at Home

ON 1st March, Sir Charles Galton Darwin relinquished his post as Scientific Adviser to the Army Council, which he has held since May last year. He returns to active direction of the National Physical Laboratory, of which he has been the head since 1938. Prof. C. D. Ellis, Wheatstone, professor of physics at King's College, London, who has been his deputy, becomes Scientific Adviser to the Army Council. Sir C. G. Darwin is a grandson of Charles Darwin, the great evolutionist.

This year's President and Chairman of the Parliamentary and Scientific Committee are Lord Samuel and Mr. E. W. Salt, M.P., respectively. The Vice-Chairman is Prof. J. A. Crowther of the Institute of Physics.

Self-sown Plants in Bombed Areas

IN a lecture at the Royal Institution on 19th February, Prof. E. J. Salisbury, the plant ecologist, gave some interesting details about the plant colonization of bombed sites. In London some 95 flowering plants and ferns had been recorded from these places. The most frequent and abundant species was the Rose-Bay Willow-herb (*Epilobium angustifolium*), occurring on 90% of the bombed sites. The second most common plant was the Groundsel (*Senecio vulgaris*), on 86% of the sites, followed by two other species of *Senecio*, *S. squalidus* and *S. viscosus* (56% and 45% respectively). Other common colonizers were the Coltsfoot (*Tussilago Farfara*), Canadian Fleabane (*Erigeron canadense*), and the dandelion.

He attributed the great abundance of the Rose-Bay Willow-herb to three causes. Firstly, its seeds only germinate freely where there is plenty of light, a condition fulfilled on a bombed site; secondly, ground which has been subjected to great heat is poisonous to many other plants and therefore the Willow-Herb has a good chance of getting there ahead of its rivals; and thirdly, it thrives on nitrates, the production of which in the soil is stimulated by burning. It is a prolific seed producer, a young plant yielding 80,000 seeds, as against 1,100 from a single groundsel plant.

After the Great Fire of London in 1666 a rare member of the Cruciferae, *Sisymbrium Irio*, invaded the ground among the ruins in such great numbers that it won itself the name "London Rocket". It was seen in very great quantities, for instance, round St. Paul's Cathedral. This time it had not reappeared, said Prof. Salisbury.

Centenary of Charter of Pharmaceutical Society

ON 18th February the Pharmaceutical Society celebrated the centenary of the granting of a Royal Charter. To mark the occasion the council of the society has instituted a travelling scholarship which will after the war enable pharmacists to study new developments in pharmaceutical practice abroad.

Mr. W. Spencer Howells, President of the Society, reviewed the achievements during the past hundred years. He described how the Society was formed to forestall the attempts of the physicians to control and repress the druggist. It had as its objects the regulation of the education of pharmacists in order to ensure the competence of those who compounded medicines, and received the Royal Charter two years after the Society was founded. The charter had been since modified and the powers of the Society extended to include the appointment of a registrar, who is required to keep registers of all chemists, druggists, and premises where poisons are retailed, and to enforce the provisions of the Pharmacy and Poisons Act, 1933, and Pharmacy and Medicines Act, 1941.

Mr. Howells stressed the educational aims of the Society and said, "In view of his education the pharmacist is increasingly regarded as the most appropriate person to supervise the production of medicines, whether in shop, hospital, or factory. With the inevitable movement of manufacture of medicines from shop and even hospital to factory, I look forward to the days when industrial experience will contribute much more substantially to pharmaceutical education than hitherto."

Radiolocation Detects Ships

IT is announced in London that radiolocation is being used to detect ships. Radiolocation equipment recently perfected now enables ships to detect other ships and planes, while planes can be fitted with apparatus by which ships below can be spotted.

A new and secret detector device, called Radar, has been held up by "the profit motive," according to a report to the American Council for Public Affairs made by Dr. Lyman Chalkley, chief economic analyst to the U.S. Government's Board of Economic Warfare. Radar works by radio and can "detect planes at night, see naval vessels through fog and darkness, and do other remarkable things, many of them still secret." In his report Dr. Chalkley says that Radar was not adequately developed before the outbreak of war because it did not appear to have any profitable peace-time uses. When the war came America "had to start practically from scratch, meanwhile losing ships and planes and men, because the profit motive had not guided up to the development of Radar from a state of laboratory curiosity to the manufacture of practical instruments."

Shoot Development of Roses

IT is of great practical importance to find means to prevent roses from untimely shooting. If roses are kept in cold storage at 32°F., they remain dormant and retain their starch reserves to the end of the season. In common storage, however, as soon as the temperature rises even for a brief spell, the rose bushes shoot more readily than other nursery material. Paul Marth of the Bureau of Plant Industry Station, Beltsville, Maryland, U.S.A., has made extensive experiments with "Ami Quinard," a hybrid tea-rose variety which tends to break dormancy early in the storage season, and he reports the results in the *Botanical Gazette*, September 1942. It was known before that growth substances prevent budding, for example the budding of potato tubers.

Marth found that in the case of roses the most effective substances were naphthalenemethylacetate and two other naphthalene compounds. Application of these agents, either in wax emulsion or in form of vapours, inhibited the vegetative buds so that the plants remained dormant throughout the normal storage season. In all treated bushes, the accumulated starch was conserved and, when planted out after the storage, they produced much greater root and top growth and also more flowers, and of a better quality, than the untreated controls.

Treatment of plants kept in cold storage seemed at first to be useless, as such plants normally retain their dormancy and food reserves. Nevertheless when planted out, they became established much more quickly and made better growth than the controls. The treated plants began immediately to send out roots and those which came from cold storage developed 100 roots, those from common storage 68, within the first seven days. Also they produced more blossoms early in the season. The untreated plants ceased their flower production and went into autumnal dormancy much sooner than the treated ones. Roses which had

enjoyed the combination of cold storage and treatment with growth substance developed 31 flowers per plant, those which had been treated while in common storage produced 21, and the untreated controls displayed only 15 flowers per plant.

Nitrate Production and Future Wars

SPEAKING at the annual lunch of the Parliamentary and Scientific Committee, Sir Robert Robinson, Waynflete professor of chemistry at Oxford, advocated a chemical means of disarming the Germans after the war. He pointed out that one essential required by all armies, navies and air forces was explosives, and these were based on nitric acid which in turn was produced from ammonia. Central Europe has no source of nitrates except from nitrogen fixation plants. Synthetic ammonia plants could not be concealed or improvised in a few months, and an international nitrogen commission would have no difficulty in maintaining a sanction in this commodity provided only we kept the will to maintain it.

Sir Robert went on to say that he had very regretfully come to the conclusion that no new major effort in chemical production was possible during the next two years in this country. We should like to see more carbide, synthetic rubber, and so on produced, but those things were really not feasible in present circumstances. In view of the fact that Sir Robert is a member of the committee considering synthetic production of rubber in this country, this remark is being taken to mean that synthetic rubber production will be left to America, at least for the duration of the war.

Conference on X-Ray Analysis

THE analysis of substances and the examination of their behaviour by X-ray diffraction methods has become of considerable importance in the war effort. The Institute of Physics is therefore arranging a second Conference on the subject to take place in Cambridge on 9th and 10th April next. The provisional programme includes a lecture on "Future Developments in X-Ray Crystallography" by Prof. J. D. Bernal, and discussions on "Quantitative Treatment of Powder Photographs", "The Fine Structure of X-Ray Diffraction", and "Fine Broadening". A report is to be presented to the Conference on the progress made in the preparation of an Index to X-Ray Diffraction Photographs, for which the Institute has undertaken to be jointly responsible with the American Society for Testing Materials and the American Society for X-Ray and Electron Diffraction.

Further particulars of the Conference and of the Index can be obtained on request from the Secretary of the Institute of Physics (*Temporary Address:* At the University, Reading.)

Scientific Warfare against Pests

FROM 1930 to 1935 the cost of laboratory research and control work to check the insects infesting stored food in the London docks was £30,000. In 1939 alone the saving affected as a result of the control measures devised in those five years amounted to £150,000—five times the original expenditure. These striking figures were given by Prof. J. W. Munro, leading economic entomologist, in a paper to the British Association of Refrigeration in London recently. Insects had to be attacked at the most vulnerable point of their life cycle, he said. He described the difficulties of fumigating large warehouses due to the fumigant gas (ethylene oxide) leaking out and the prohibitive cost. An attempt was made to kill by spraying the caterpillars of the moth *Plodia interpunctella* which were crawling on fruit boxes and around the warehouse walls. A research student in his laboratory had noticed that the moths showed a marked rhythm of emergence, leaving their chrysalides about dusk when the temperature of the day fell. It seemed possible that if the moths in the warehouse also showed a similar regularity then they might be destroyed by spraying. He tried a rather bold experiment because spraying of the caterpillars was a failure owing to their habit of hiding in cracks and crevices where the spray could not reach them. A fine spray of pyrethrum-in-oil was used at night, and this not only killed the moths in large numbers but also settled and formed a film which proved fatal to caterpillars which crawled in it. This lucky strike proved so effective that in the next season there was no need to spray at dusk because it was found that a regular routine of spraying in the daytime was sufficient. Successful control of *Plodia* in both barges and warehouses had subsequently been achieved in London, Bristol, Liverpool, Manchester, and Glasgow.

Prof. Munro expressed the belief that it would be quite practicable to keep infestation of foodstuffs and food stores well below the economic danger point by a scientific control of temperature and humidity, the prime factors governing the increase of insect populations. The entomologist could provide the chemical engineer with the data needed to devise ways and means of controlling insect pests. "Since the war the fact that the infestation of premises and commodities by insects must now be compulsorily notified has still further emphasized the fact that infestation is not inevitable, and has even branded it as bad business. I cannot believe that, even if after the war the control now exercised by the Ministry of Food disappears, industry will itself permit a return to the conditions of storage which were tolerated ten or fifteen years ago. I know that among the more enterprising wharfingers, warehousemen and merchants the elimination of insects and rats in their new premises will receive consideration," he commented.

Scientists need a Social Sense

AT a London meeting of the Institution of Civil Engineers (wireless section) on 3rd February, Prof. Willis Jackson, of the electrotechnics department of Manchester University, suggested that scientists and technicians should be better educated about society, so that they could understand the way in which their discoveries and inventions would help to improve the amenities of life and the repercussions of those discoveries upon social stability which resulted. They must have some appreciation of the social implications of their creative efforts, and he recommended that students should be stimulated at the undergraduate stage by a course giving a clear historical understanding of the parallel growth of science and engineering on the one hand, of social customs, institutions and relations on the other, and of the way in which those factors reacted upon each other. He thought that before the war production of modern machinery in Britain was lagging behind owing to the lack of properly trained scientists and engineers. They needed a broad basis for their training, but existing courses ignored the value of encouraging the study of non-technical subjects. He advocated that the embryo technician should spend a year in industry before going to a university, and that this year should count as a year's national service in the event of that feature being introduced in this country.

Social Life in the Ant World

ROBERT GREGG of the University of Chicago, in a recent paper on "The Origin of Castes in Ants", (*Ecology*, vol. 23, July 1942), poses and answers an interesting question: "Whether caste differences in social insects are to be attributed alone to germinal (genetic) causes contained in the egg or are the result of causes acting from without, is a controversial question. The bulk of evidence in the literature seems to point to environmental control."

Former investigators had shown that rich food tends to produce queens and soldiers rather than workers. But the experiments of Castle with termites revealed another, surprising influence. He found that if a caste is present in strong numbers, this very fact prevents or delays the development of more individuals of the same caste. If the caste is removed from the colony, new members are allowed to mature. He ascertained that substances secreted from the insect body and conveyed to the larvae had an inhibitory effect which was caste-specific. Gregg boldly names these inhibitory substances "social hormones".

Gregg's own experiments, undertaken with the ant *Pheidole Morrisi*, aimed at discovering the role which the castes themselves play in the determination of immature insects. The food was kept uniform in quality and quantity throughout all experiments.

Gregg established three kinds of colonies: (1) controls containing queens, workers and soldiers, just as gathered from the fields (C); (2) colonies of queens and workers only (W); and (3) colonies of queens and soldiers only (S). Queens had to be present everywhere as a source of eggs. The question was what would become of these eggs?

Concerning the workers, there is nothing interesting to report. Worker ants appeared in large numbers in all colonies. The average brood rate W:S was in W colonies 25:1, in C 40:1, and in

S 112:1. In the soldier nests, no soldiers were produced before the worker population was rather large.

How far the "cannibalism" of the ants may contribute to the maintenance of an equilibrium, is not clear. Piles of dismembered bodies were always found though ample food was provided. Like the witch in Hansel and Gretel, "the workers assiduously cared for the young,

In Pheidole, the castes are very distinct and can be easily diagnosed, also at pupation. The pupae are not enclosed in cocoons. The greatest advantage was that the soldiers were quite independent of the workers in caring for themselves, the brood and the queens. They licked and fed the larvae and carried the young most delicately despite their powerful jaws. They groomed and fed the queen, and the S colony behaved in all respects as if workers had been present. The caste seemed to be determined at a late stage of larval development, certainly after hatching.

Gregg postulates a "social hormone" for his ants, but does not give any evidence for it.

Coal for Plastics Industry

Recently there has been a tendency for oil to take the lead as the most important raw material from which plastics can be made, but the view is growing in this country that it is to coal that we must look as the starting-point of this vital industry. Last year this view was stressed very forcibly by the chief chemist of the Anglo-Iranian Oil Company and received widespread support. The theme was taken up by Mr. Kenneth M. Chance at the annual general meeting of British Industrial Plastics, Ltd., in London this February. Mr. Chance said there were few signs that coal and limestone, this country's native raw materials for plastics, would be used to the best advantage in plastics production.

It had been left to Soviet Russia to translate that forecast into practical operation. There was a lack of enterprise here in not developing carbide plants, which provided the basis of the vinyl plastics, and cyanamide, which formed the basis of another range of plastics, including some aminoplastics. As long ago as 1935 Germany was making half a million tons of carbide a year. It might well happen that before long the yardstick by which the industrial prosperity of a country was measured would be carbide in place of steel. Why were the natural resources of this country so neglected? "I have given much thought to this problem," said Mr. Chance. "Looking back over the centuries one finds that from Newton onwards this country has never lacked men of science whose ideas and inventions have laid the foundations of the revolutions that have taken place in industry, and yet we have allowed of late other countries to translate those ideas and inventions into industrial practice. The conclusion I have come to is that we have been so immersed in commerce, in the acquisition of wealth from other lands, that we have ignored the fundamental truth that commerce should be the servant of industry".

Food Yeast: Source of Protein and Vitamin B from Waste Molasses

The first large scale attempt in the British Empire to produce a foodstuff rich in protein and the vitamin B complex by means of Food Yeast is to be made in Jamaica. The plant which is being paid for by the Colonial Office will cost £25,000.

The preliminary research has been carried out in the Chemical Research Laboratory of the D.S.I.R. It has long been known that the protein of micro-organisms is of the same high nutritive value as animal protein, and recently it was discovered that micro-organisms such as yeasts build up all the members of the vitamin B complex. To secure a suitable micro-organism for vitamin B production a selection had to be made from the countless types known to science. The organism finally to be chosen had preferably to be a type which could be produced in bulk from the cheapest possible raw materials, as for instance waste molasses and ammonia. It also had to be a type which would reproduce rapidly and be harmless to man when eaten. For the factory in Jamaica it has been decided to concentrate on an organism known as *Torula utilis*, which has been developed at the Chemical Research Laboratory from a yeast which was well known before the war.

Food Yeast can be produced from waste molasses when nitrogen, in the form of ammonia or ammonium salts, and phosphorus are added. Its production is extremely rapid. The manufacture of Food Yeast can proceed continuously by the simple expedient of pouring into a vat at one end a solution of molasses and the necessary ammonia and phosphate and of simultaneously withdrawing at the other end of the vat an equivalent volume of yeast in suspension, which is then washed to remove waste products and dried. It is considered that the product may be of importance during the immediate post-war period when the depleted animal stock of Europe will be insufficient to provide meat and milk for the underfed populations of the occupied countries. In the tropical and sub-tropical countries of the British Empire Food, Yeast may also find an important application, for native diets are often deficient in vitamin B. It is estimated that Food Yeast can be supplied at 6d. a pound, and half an ounce taken daily would ensure to the native a sufficiency of vitamin B complex.

Two Interesting Meteors

Accounts are given of two large meteors in American publications which have appeared quite recently. The first meteor, described by J. Hugh Pruett in "Astronomical Society of the Pacific," Leaflet No. 165, November, 1942, under the title "The Portland Meteor and Resulting Meteorite," was seen about 8 A.M. on July 2nd, 1939, and was responsible for producing a loud, grating noise and a violent jarring of houses all over Portland. Exaggerated accounts were given in the Press in other countries, and *La Nazione*, in Italy, reported that Portland, U.S.A., was completely destroyed by the celestial visitor. Fortunately no material damage was done, but many people's nerves were frayed by the terrific detonation caused by the compressional wave which the meteor produced in its flight. Making use of the data provided by a large number of people who saw the fireball, Dr. Fletcher Watson, of Harvard, computed its path. It moved with a velocity of nearly 40 miles a second and first became visible near the northern Oregon coast line, passed over northern Portland, and then disappeared beyond Bonneville at a height of 10 miles. A remnant of the meteor was picked up on a farm about 15 miles east of Portland next day, and this, which weighed ½ lb., was found to belong to the rare type of stony meteorites known as Howardites. These are friable and easily destroyed because the materials composing them are loosely cemented together. The remaining portion of the meteorite, after a small part had been removed for analysis, is now in the possession of Mr. Pruett, University of Oregon, Pacific Director of the American Meteor Society.

The other meteor is described in *Sky and Telescope*, November, 1942, by Oscar E. Monning, and is specially remarkable for the length of its path, which may have been nearly 600 miles. It became visible north of Shreveport, at a height of 80 miles and in about 30 seconds had moved to a point less than 20 miles north and east of Guymon. There is considerable doubt about its height at the end, but 15 miles is suggested as somewhere near the true figure. As it appeared at 9.30 C.W.T. on August 7th (1942) there was a certain amount of twilight at the time, especially in the more western regions, but the magnitude of the meteor was about – 4, equal to that of Venus, and it was a conspicuous object during the whole time of its flight. It was accompanied by a long tail, and it left a trail which was about 30 degrees in length but which persisted for a very short time—from 5 to 10 seconds. As its path was nearly horizontal it encountered very rarified atmospheric conditions during the greater part of its flight. This may partly explain the absence of detonations and also the slight evidence for the landing of any fragments. If there were any fragments none of them has been found.

"Discovery" for January and February

The demand for the January and February numbers of *Discovery* exceeded the number printed, which has necessitated a reprinting of these two issues. Readers and subscribers who have been disappointed at not being able to secure these two first numbers of Volume IV will now be able to do so.

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